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Background Document for Railroad Noise Emission Standards

Environmental Protection Agency

December 1975

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BACKGROUND DOCUMENT
FOR
RAILROAD NOISE EMISSIONS
STANDARDS

DECEMBER 1975

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

This document has been approved for general availability. It does not constitute a standard, specification or regulation.

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PREFACE

On December 31, 1975, the Environmental Protection Agency issued a regulation governing noise emissions from interstate rail carriers. That regulation was issued under Section 17 of the Noise Control Act of 1972.

This document presents and discusses the background data used by the Agency in setting the standards contained in the regulation. Presented here is a comprehensive exposition on the most up-to-date available information on the environmental, technological, and economic aspects of railroad noise.

TABLE OF CONTENTS

Section Page

1 PROLOGUE 1-1
STATUTORY BASIS FOR ACTION 1-1
INTERNAL EPA PROCEDURE 1-3
PREEMPTION 1-4
Noise Emission Standards on Railroad Equipment 1-4
Noise Emission Standards on Railroad Facilities 1-5
Design or Equipment Standards 1-5
Use, Operation, or Movement Controls 1-6
Receiving Land Use Standards 1-6

2 SUMMARY OF WHAT THE REGULATION REQUIRES 2-1
APPLICATION OF BEST AVAILABLE TECHNOLOGY TAKING INTO ACCOUNT THE COST OF COMPLIANCE 2-1
LEVELS OF TRAIN NOISE CONTROL 2-2
Locomotive Noise – Vehicle at Rest 2-2
Locomotive Noise – Vehicle in Motion 2-3
Railcar Noise – Vehicles in Motion on Line 2-3
Railcar Noise – Vehicles in Motion in Yards 2-3
REVISION OF THE PROPOSED REGULATION PRIOR TO PROMULGATION 2-4
NOISE EMISSION STANDARDS INTERSTATE RAIL CARRIER NOISE REGULATION 2-6

3 DATA BASE FOR THE REGULATION 3-1

4 THE RAILROAD INDUSTRY 4-1
ECONOMIC STATUS 4-1
EMPLOYMENT 4-3
HEALTH AND GROWTH OF THE INDUSTRY 4-5
Health of the Industry 4-5
Growth of the Industry 4-7

5 RAILROAD NOISE SOURCES 5-1
OVERVIEW OF THE PROBLEM 5-1
CONSIDERATION OF RAILROAD NOISE SOURCES FOR FEDERAL REGULATIONS 5-2
Office Buildings 5-2
Repair and Maintenance Shops 5-3

TABLE OF CONTENTS (Cont'd)

Section Page

5 Terminals, Marshalling Yards, Humping Yards, and Specifically Railroad Retarders 5-3
Horns, Whistles, Bells, and Other Warning Devices 5-5
Special Purpose Equipment 5-6
Track and Right-of-Way Design 5-7
Trains 5-9
CHARACTER OF RAILROAD NOISE SOURCES AND ABATEMENT TECHNOLOGY 5-9
Locomotives 5-9
Diesel-Electric Locomotives 5-9
Locomotive at Rest 5-11
Locomotive in Motion 5-11
Locomotive Noise Abatement 5-21
Abatement By Equipment Modifications 5-21
Noise Abatement By Operational Procedures 5-26
Electric/Gas Turbine Locomotives 5-27
Wheel/Rail Noise 5-27
Wheel/Rail Noise Abatement 5-29
Retarder Noise 5-33
Retarder Noise Abatement 5-34
Benefits 5-34
Costs 5-35
Car-Car Impact Noise 5-36
Warning Devices 5-36
Public Address Systems 5-39
Maintenance and Repair Shops 5-39
Refrigerator Cars 5-39
Auxiliary Diesel Engines 5-39

6 GENERAL PROCEDURE TO MEASURE RAILROAD NOISE 6-1
INTRODUCTION 6-1
SUBPART C–MEASUREMENT CRITERIA 6-2
201.20 Applicability and Purpose 6-2
201.21 Quantities Measured 6-2
201.22 Measurement Instrumentation 6-2
201.23 Acoustical Environment, Weather Conditions and Background Noise 6-3
201.24 Procedures for the Measurement of Locomotive and Rail Car Noise 6-5

TABLE OF CONTENTS (Cont'd)

Section Page

7 ECONOMIC EFFECTS OF A RETROFIT PROGRAM 7-1
  INITIAL ECONOMIC ANALYSIS 7-2
    The Impact on the Railroad Industry 7-2
      General Impact 7-2
      The Impact on Marginal Railroads 7-15
      The Impact on Bankrupt Railroads 7-18
    The Impact on Users of Rail Transportation 7-18
      The Effect on Railway Freight Rates 7-18
      The Effect on Quality of Service 7-24
    Summary and Conclusions Concerning Initial Economic Analysis 7-25
      Impact on the Railroad Industry 7-25
    Impact on Users of Rail Services 7-26
  SUBSEQUENT ECONOMIC COST AND IMPACT ANALYSES 7-26
    The Cost of Retrofitting Mufflers on Locomotives 7-26
      Initial Direct Costs 7-27
      Initial Indirect Costs 7-33
      Continuing Costs 7-37
      Summary of Locomotive Retrofit Costs 7-38
    Economic Impact of Muffler Retrofit 7-38
      Labor Supply 7-40
      Impact on Railroad Revenue and Profits 7-44
      Financial Impact 7-45
      Freight Diversion as a Result of Differential Impacts of Fuel Costs 7-47
      Impacts on Consumers 7-52

8 ENVIRONMENTAL EFFECTS OF THE FINAL REGULATION 8-1
  INITIAL ANALYSIS OF IMPACT RELATED TO ACOUSTICAL ENVIRONMENT 8-1
    Case Studies of Railroad Lines 8-1
    Analysis of Train Noise Impact 8-1
  REFINEMENTS ON INITIAL ANALYSIS OF IMPACT RELATED TO ACOUSTICAL ENVIRONMENT 8-11
    Miles of Railroad Track 8-11
    Population Densities 8-12
    Traffic Volume in Urban Areas 8-12
    People Exposed 8-15

TABLE OF CONTENTS (Cont'd)

Section		Page
8	Impact Related to Land	8-19
	Impact Related to Water	8-19
	Impact Related to Air	8-19
	DAY NIGHT EQUIVALENT NOISE LEVEL (L_{dn})	8-21
	EXCESS ATTENUATION OF RAILROAD NOISE	8-21
9	ECONOMIC EFFECTS OF THE FINAL REGULATION	9-1
	EQUIVALENT ANNUAL INCREASED LOCOMOTIVE MANUFACTURING COSTS ATTRIBUTABLE TO MUFFLER INTRODUCTION	9-1
	EQUIVALENT ANNUAL INCREASED FUEL COSTS ATTRIBUTABLE TO MUFFLER INTRODUCTION ON NEWLY MANUFACTURED LOCOMOTIVES (OVER AN ESTIMATED 25-YEAR FLEET REPLACEMENT PERIOD)	9-2
	MUFFLER REPLACEMENT COSTS	9-2
	SUMMATION OF THE MAJOR COSTS INCURRED THROUGH THE ADDITION OF MUFFLERS TO NEWLY MANUFACTURED LOCOMOTIVES	9-3
Appendix A	MAJOR TYPES OF DIESEL-ELECTRIC LOCOMOTIVES IN CURRENT U.S. SERVICE (1 JANUARY 1973)	A-1
Appendix B	REVIEW OF THE AUDIBLE TRAIN-MOUNTED WARNING DEVICES AT PROTECTED RAILROAD HIGHWAY CROSSINGS	B-1
Appendix C	OPERATING RAILROAD RETARDER YARDS IN THE UNITED STATES	C-1
Appendix D	SUMMARY OF YARD NOISE IMPACT STUDY	D-1
Appendix E	GENERAL MOTORS CORPORATION LOCOMOTIVE EXHAUST MUFFLER RETROFIT COST STUDY REPORTS	E-1
Appendix F	GENERAL MOTORS CORPORATION ADDITIONAL COMMENTS ON THE ENVIRONMENTAL PROTECTION AGENCY PROPOSED RAILROAD NOISE EMISSION STANDARDS	F-1
Appendix G	MUFFLER DESIGN FOR LOCOMOTIVES	G-1
Appendix H	DETAILED MUFFLER DESIGNS AND PERFORMANCE ESTIMATES	H-1

TABLE OF CONTENTS (Cont'd)

Section

Appendix I SPACE AVAILABILITY FOR MUFFLERS INSIDE LOCOMOTIVES A-I

Appendix J LOCOMOTIVE NOISE MEASUREMENTS TAKEN IN CONJUNCTION WITH HARCO MANUFACTURING COMPANY AND ADDITIONAL MEASUREMENTS A-J

Appendix K EXHAUST NOISE MEASUREMENTS FOR THE GP-9 LOCOMOTIVE A-K

Appendix L TRIP TO MONTREAL LOCOMOTIVE WORKS AND MEASUREMENTS OF M-420 LOCOMOTIVE A-L

Appendix M THE USE OF MUFFLERS ON LARGE DIESEL ENGINES IN NONRAILROAD APPLICATIONS: RESULTS OF A BBN SURVEY A-M

Appendix N AMTRAK EXPERIENCE WITH MUFFLED LOCOMOTIVES A-N

Appendix O REFRIGERATOR CARS A-O

Appendix P APPLICABILITY OF TRACK AND SAFETY STANDARDS TO NOISE A-P

Appendix Q RAIL CAR NOISE LEVEL DATA A-Q

Appendix R ANALYSIS OF PUBLIC COMMENTS ON THE ENVIRONMENTAL PROTECTION AGENCY PROPOSED RAILROAD NOISE EMISSION STANDARDS A-R

LIST OF ILLUSTRATIONS

Figure		Page
5-1	Effect of Fan Noise on the A-Weighted Spectrum of EMD GP40-2 Locomotive Noise at 55 ft (Engine Access Doors Open)	5-16
5-2	Diesel-Electric Locomotive Passbys	5-17
5-3	Peak Locomotive Noise Level vs. Speed	5-19
5-4	Relationship Between Maximum Noise Level and Number of Coupled Locomotives	5-20
5-5	Wheel/Rail Noise Measured on Level Ground and on a 1% Grade	5-30
5-6	Measured Wheel/Rail Noise	5-30
5-7	Average, and Minimum Rail-Wheel Sound Level vs. Speed for Typical Railroad Cars on Welded and Bolted Rail	5-31
5-8	Retarder Squeal Amplitude Distribution	5-33
5-9	Car-Car Impact Noise Time Histories	5-37
6-1	Test Site Clearance Requirement for Locomotive Stationary, Locomotive Pass-by, and Rail Car Pass-by Tests	6-4
7-1	Cost of Retrofit Program as a Function of Compliance Period	7-14
7-2	Distribution of Railroads by Retrofit Cost as a Percent of Net Operating Revenue for 2- and 5-year Compliance Periods	7-16
7-3	Patterns in Maintenance of Railroad Equipment and Stores	7-41
7-4	Effect of Fuel Prices on Distribution of Freight	7-51
8-1	L_{dn} vs Distance From the Track for the Dorchester Branch of Penn Central	8-5
8-2	L_{dn} vs Distance From Track for National Average Train Traffic	8-6
8-3	Distance From Track at Which Various L_{dn} Occurs Around the Dorchester Branch of the Penn Central	8-7
8-4	Thousands of People Exposed to Various L_{dn} by 7.2 Miles of Track on the Dorchester Branch of the Penn Central	8-8
8-5	Distance From Track at Which Various L_{dn} Occur Due to National Average Train Traffic	8-9
8-6	Millions of People Exposed to Various L_{dn} by National Average Train Traffic	8-10
8-7	Influence of Frequency-Dependent Attenuations of Locomotive Noise Spectrum	8-22
8-8	Influence of Frequency-Dependent Attenuations of Wheel/Rail Noise, Train No. 6, Region 2	8-23

LIST OF TABLES

Table		Page
4-1	National Income Originating in the Transportation and Rail Sectors	4-2
4-2	Intercity Freight	4-2
4-3	Percent of National Income Originating in the Transportation Sector and the Rail Sector as a Percent of Transportation	4-3
4-4	Employment in the Rail Industry Relative to the National Economy	4-4
4-5	Index of Output per Man Hour and Wages	4-4
4-6	Percent of Gross Revenue Carried Through to Net Operating Income Before Federal Income Taxes	4-6
5-1	Effect of Throttle Position on Engine Power and Noise Levels	5-10
5-2	Stationary Noise Emission Data for General Motors and General Electric Locomotives	5-12
5-3	Source Contributions to Locomotive Noise Levels	5-16
5-4	Locomotive Passby Noise Emission Levels Measured at 100 Feet	5-18
5-5	Locomotive Noise Levels Expected from Exhaust Muffling, Throttle 8	5-23
5-6	Switcher Locomotives in Service	5-25
5-7	Noise Levels from Electric and Gas-turbine Trains	5-28
7-1	Muffler Costs per Locomotive	7-2
7-2	Distribution of Locomotives by Manufacturer, Type, and Region	7-4
7-3	Total Direct Cost of Retrofit Program	7-4
7-4	Annual Direct Cost of 2- and 5-Year Retrofit Programs	7-6
7-5	Average Maintenance Interval by District	7-7
7-6	Days Lost Due to Retrofit	7-7
7-7	Equation for Total Lost Time per District	7-8
7-8	Lost Locomotive Days by Region and Compliance Period	7-9
7-9	Regional Annual Revenue per Locomotive Day	7-10
7-10	Estimated Lost Revenue Due to Retrofit	7-10
7-11	Annual Net Cost of Retrofit	7-12
7-12	Total Net Cost of Retrofit Program	7-13
7-13	Annual Retrofit Cost as a Percentage of 1971 Total Operating Revenue	7-13
7-14	Annual Retrofit Cost as a Percentage of 1971 Net Operating Revenue	7-15
7-15	Number of Railroads in Unfavorable Financial Position Relative to Eight Indicators	7-19
7-16	Number of Railroads Designated as Being in Financial Difficulty by One or More Financial Indicators	7-20
7-17	Net Cost of Muffler Retrofit Program for the Seven Bankrupt Class I Railroads	7-20

LIST OF TABLES (Cont'd)

Table		Page
7-18	Rate Increase That Would Enable Railroads to Recover Retrofit Expenses	7-22
7-19	Annual Locomotive Days Taken Up by Retrofit Program	7-24
7-20	Hardware Modifications and Material Costs for Turbocharged Road Locomotives	7-28
7-21	Average 1973 Hourly Wage Rate for Skilled and Other Workers	7-29
7-22	1973 Weighted Average Hourly Labor Cost Deviation	7-30
7-23	Labor Man-Hours and Total Labor Cost for Muffler Retrofit Program	7-31
7-24	Initial Direct Costs of Retrofitting Exhaust Mufflers to Locomotives	7-33
7-25	Days Lost Due to Retrofit	7-35
7-26	Number of Locomotives by Type	7-37
7-27	Summary of Initial Locomotive Retrofit Costs for a 2-Year Program	7-39
7-28	Summary of Annual Costs of Locomotive Retrofit for a 2-Year Program	7-39
7-29	Levels of Employment and Average Hours Worked in 1970 and 1972 Compared to 1973	7-43
7-30	Man-Hours Required for Locomotive Retrofit	7-44
7-31	Ratio 1–Current Assets/Total Assets	7-47
7-32	Ratio 2–Operating Expenses/Operating Revenue	7-48
7-33	Ratio 3–Total Liabilities Less Stockholder Equity/Total Assets	7-48
7-34	Ratio 4–Income After Fixed Charges/Total Assets	7-49
7-35	Ratio 5–Retained Earings/Total Assets	7-49
7-36	Ratio 6–Net Income/Total Assets	7-50
7-37	Ratio 7–Net Income/Operating Revenue	7-50
7-38	Effect of a 1-Percent Rail Freight Rate Increase on Commodity Prices	7-53
7-39	Freight Rate Necessary to Offset Increased Costs Due to Retrofit	7-54
8-1	Land Use Near Railroad Lines	8-2
8-2	Train Traffic and Community Characteristics Near Typical Railroad Lines	8-3
8-3	Distribution of Urban Grade Crossings by Volume of Train Traffic	8-13
8-4	Computation of National Average Direct-Powered Train Traffic	8-13
8-5	Average Train Characteristics	8-14
8-6	Present Distribution of People by L_{dn} Interval	8-18
8-7	Present and Projected Populations Exposed to Various Levels of L_{dn}	8-18
8-8	Distribution of People by L_{dn} Interval Assuming Muffler Retrofit	8-19
8-9	Equivalent Noise Impact for Present and Quieted Locomotive Populations	8-20

Section 1

PROLOGUE

STATUTORY BASIS FOR ACTION

In Section 2 of the Noise Control Act, Congress expressed its judgment "that while primary responsibility for control of noise rests with state and local governments, Federal action is essential to deal with major noise sources in commerce, control of which require national uniformity of treatment." Congress also declared within Section 2 of the Act "that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare."

As a part of this essential Federal action, Section 17 requires the Administrator to publish proposed noise emission regulations that "shall include noise emission standards, setting such limits on noise emission resulting from operation of the equipment and facilities of surface carriers engaged in interstate commerce by railroad which reflect the degree of noise reduction achievable through the application of the best available technology, taking into account the cost of compliance." After the effective date of such a regulation, no state or political subdivision thereof may adopt or enforce any standard applicable to noise emissions resulting from the operation of the same equipment or facility of such carrier unless such standard is identical to a standard applicable to noise emissions resulting from such operations as prescribed by these regulations. The Administrator, after consultation with the Secretary of Transportation may, however, determine that the state or local standard, control, license, regulation, or restriction is necessitated by special local conditions and is not in conflict with regulations promulgated under Section 17. Procedures for state and local governments to apply for an exemption under Section 17(c) (2) of the Act will be published by this Agency shortly after promulgation of this regulation.

These sections of the Noise Control Act reflect the desire of Congress to protect both the environment and commerce through the establishment of uniform national noise emission regulations for the operation of interstate railroad equipment and facilities. Such equipment and facilities require national uniformity of treatment to facilitate interstate commerce because certain types of interstate railroad equipment and facilities operations would be unduly burdened by conflicting state and local noise controls. Preemption under Section 17 occurs only for state or local noise regulations on equipment and facilities on which Federal regulations are in effect. When national uniformity of treatment is not needed, Congress recognized the primary responsibility of state and local governments to protect the environment from noise. State and local regulations on noise emissions resulting from the operation of equipment and facilities of surface carriers engaged in interstate commerce by railroad that are not preempted by applicable Federal regulations under Section 17 are subject to the Commerce Clause of the U.S. Constitution. Under that Clause, any state or local regulations that constitute an undue burden on interstate commerce cannot stand.

The Act directs that Federal regulations on interstate railroad equipment and facilities under Section 17 are to include noise emission standards setting limits on noise emissions resulting from their operation that reflect the degree of noise reduction achievable through the application of the best available technology, taking into account the cost of compliance. Based upon the strict language of the Noise Control Act, its legislative history, and other relevent data, these requirements are further clarified:

- *"Best available technology"* is that noise abatement technology available for application to to equipment and facilities of surface carriers engaged in interstate commerce by railroad that produces meaningful reduction in the noise produced by such equipment and facilities. "Available technology" is further defined to include:
    - Technology that has been demonstrated and is currently known to be feasible.
    - Technology for which there will be a production capacity to produce the estimated number of parts required in reasonable time to allow for distribution and installation prior to the effective date of the regulation.
    - Technology that is compatible with all safety regulations and takes into account operational considerations including maintenance and other pollution control equipment.
- *"Cost of compliance"* is the cost of identifying what action must be taken to meet the specified noise emission level, the cost of taking that action, and any additional cost of operation and maintenance caused by that action.

In preparing the final regulation the Administrator has given full consideration to cost of compliance and available technology and has consulted with the Secretary of Transportation to assure appropriate consideration for safety and for availability of technology.

Further, recognizing that the Noise Control Act was enacted to protect the public from adverse health and welfare effects due to noise, EPA has also considered the impact of railroad noise taking into account the levels of environmental noise requisite to protect the public health and welfare with an adequate margin of safety, as published by EPA in March 1974 in accordance with Section 5(a)(2) of the Act.

Accordingly, EPA has developed and is now implementing an interstate rail carrier noise control strategy based on Section 17 of the Act that should prove to be effective in reducing environmental noise from railroads in many areas to the levels identified as protective of public health and welfare. The strategy calls for the reduction of the noise from railroad locomotives and rail cars to the lowest noise levels consistent with the noise abatement technology available, taking into account the cost of compliance.

Compliance regulations are to be developed and promulgated under separate rule making by the Department of Transportation, as called for in Section 17(b) of the Act.

The legal basis supporting promulgation of the regulation was set forth in substantial detail in the notice of proposed rule making published in the *Federal Register* on July 3, 1974 (39 FR 24580). In the same publication, notice was given of the availability of the "Background Document and

Environmental Explanation for the Proposed Interstate Rail Carrier Noise Emission Regulations," which provided the factual basis for the standards proposed, applicable measurement methodology, costs of compliance with the proposed standards, and the public health and welfare benefits expected. Public comment was solicited, with the comment period extending from July 3, 1974, to August 17, 1974.

To ensure that all issues involved in the proposed regulation and Background Document were fully addressed prior to promulgation of the final regulation, a special consultation meeting was announced in the *Federal Register* of August 6, 1974 (39 FR28316) and was consequently held on August 14, 1974, in Des Plaines, Illinois. The principal issues reviewed at this meeting related to the adequacy of the available technology to meet requirements in the proposed standards and the impact of Federal preemption on state and local noise regulations. The transcript of the meeting has been included as a portion of the total body of public comment received.

Public comments received during the public comment period are maintained at the EPA Headquarters, 401 M Street, S.W., Washington, D.C. 20460 and are available for public inspection during normal working hours.

In the future, the Agency may propose further regulations concerning railroad noise, as the need for the feasibility of such regulations are demonstrated. Such regulations may be proposed as amendments to that part of the Code of Federal Regulations established by the regulatory action currently taken by the agency under Section 17 or may be proposed pursuant to EPA authority to set noise emission standards for new products specified in Section 6 of the Act.

INTERNAL EPA PROCEDURE

The rulemaking process of EPA began with the publication of an Advanced Notice of Proposed Rulemaking in the *Federal Register*. At that time, EPA informed the public of the requirement that regulations be developed and requested that pertinent information be submitted to the Agency for consideration. A task force composed of Federal, state, and local government officials, and consultants was then formed to develop recommendations for these regulations. The Office of Noise Abatement and Control considered these recommendations together with the recommendations of the EPA Working Group, composed of representatives from various offices of the Agency, in formulating the proposed regulations. After the Deputy Assistant Administrator for Noise Control Programs approved the proposed regulations, they were submitted to the Assistant Administrator for Air and Waste Management Programs, who has responsibility for the Noise Control Program as well as several other programs. Following the Assistant Administrator's approval, the proposed regulations were submitted to the EPA Steering Committee, which is composed of the Deputy Assistant Administrators of EPA.

Upon the Steering Committee's approval, the proposed regulations were forwarded to the Office of Management and Budget, and other interested Federal agencies, for review. After those comments were analyzed and satisfactorily addressed, the proposed regulations were submitted through the Assistant Administrator for Air and Waste Management Programs to the EPA Administrator for final approval and ultimate publication in the *Federal Register*. The resulting public comments were analyzed, and a recommendation for the final regulation was prepared by the Deputy Assistant Administrator for Noise Control Programs. The final regulations were then submitted to the Assistant Administrator for Air and Waste Management Programs and the review process followed in the case of the proposed regulations was initiated again. This process culminated in the promulgation of the regulation.

PREEMPTION

Though the Noise Control Act speaks of preemption in unequivocal terms, the various sources of railroad noise are subject to such complex interrelationships that it is impossible to identify all regulations *a priori* as either preempted or not preempted. It is necessary to examine the regulation in question, the sources it purports to control, the activities to which it relates, and the reasonableness of the various alternative means of complying. As to those regulations subject to preemption, the preemptive effect may be waived under Section 17(c) (2) if the Administrator determines that the regulation is necessitated by special local conditions and is not in conflict with EPA regulations. It is anticipated that all such determinations as to not only special local conditions but also the preempt status of state and local regulations impacting railroads would be handled by EPA. The Agency is currently preparing guidelines that will specify procedures to be followed by state and local governments when questions of the preemptive effect of Federal rail carrier noise regulations are at issue.

In view of the many comments received in response to the proposed regulation, the following discussion of preemption is intended to clarify the Agency interpretation of the preemptive effect of the regulation.

State and local governments can deal with railroad noise problems in several different ways. The first, the method adopted by EPA in the regulation, is to set emission standards on railroad equipment to reduce the noise produced at the source. Second, they can set noise emission standards on facilities where rail operations occur. A variation of this approach is the use of property line standards, for which measurements are taken at the railroad property boundaries. Third, they may impose affirmative requirements on railroad equipment or facilities ("design" or "equipment" standards), such as the installation of mufflers on locomotives, the elimination of wheel flats on rail cars, or the construction of noise barriers along rights of way. A fourth possibility is to regulate, license, control or restrict the use, operation or movement of any equipment or facility, for example prohibiting idling of locomotives on sidings within communities or prohibiting railroad yard operations between the hours of 10:00 p.m. and 6:00 a.m. Fifth, a state or community may set receiving land-use standards for property impacted by railroad noise, for example requiring that noise levels at the property line of residential property not exceed 55 dBA L_{dn}. Each of these methods presents special problems that affect the determination of the preemptive relationship of the EPA railroad noise regulation.

Noise Emission Standards on Railroad Equipment

The Noise Control Act provides that after the effective date of the standards promulgated for locomotives and rail cars, no state or local subdivision may adopt or enforce any noise emission standard on locomotives or rail cars unless it is identical to the Federal standard. They may adopt and enforce noise emission standards on other pieces of equipment not covered by EPA regulations, such as retarders and railroad construction equipment. They may also adopt standards for locomotives and rail cars if such standards are identical to the EPA standards.

Determining the preemptive effect of a noise emission standard is, however, complicated by the fact that a standard for total noise emissions from the operation of a piece of equipment may not differentiate between the elements contributing to the noise. When this is the case, the Administrator believes that when any given element of noise is either (1) generated by a source that is an integral part of the federally regulated equipment or (2) is a component of the total noise generated by the federally regulated equipment, the regulation of that element by state and local governments is subject to preemption. Specifically, these elements include the noise from refrigerator units on refrigerator cars, auxiliary power units on locomotives, and noise caused by the condition of track. The noise caused by retarders, however, is a separate source of noise that will not be present during compliance measurement for the rail car standard and, as such, is not subject to preemption.

Noise Emission Standards on Railroad Facilities

State and local governments may enact noise emission standards for facilities that EPA has not regulated. However, in the judgment of EPA, the preemptive purpose of Section 17 of the Noise Control Act requires that such regulations not be permitted to do indirectly what is specifically preempted. That is, state and local governments may not control the noise emissions of locomotives and rail cars by setting noise emission limits on yards where the noise limit is, in effect, a limit on locomotive and rail car noise. Noise emission standards may be adopted and enforced on facilities where rail cars and locmotives do not operate. Where federally regulated equipment is a noise contributor in a facility on which a state or local government proposes to set a noise emission standard, such as a marshalling yard, such a regulation may or may not be preempted.

If compliance could reasonably be achieved by action that did not require modification of or controlling the use of the operation of locomotives and rail cars, then it would be permisssible. If the only way compliance could reasonably be achieved were to take actions preempted by Federal regulations, then such a standard is preempted. Questions such as the availability and reasonableness of alternative means of compliance will be dealt with by EPA under procedures now being developed to guide states and localities in dealing with railroad noise in light of Federal preemption.

Design or Equipment Standards

The Noise Control Act does not deal explicitly with regulations that require the installation of noise abatement devices or the application of specified maintenance or repair procedures. EPA believes that this is another area in which the preemptive purpose of Section 17 requires that the effect of state or local regulations on federally regulated equipment or facilities be analyzed. The intended result of Section 17(c) is that, except in cases in which EPA has made a special determination, state noise regulations on locomotives or rail cars will not require that interstate rail carriers modify these federally regulated pieces of equipment. Accordingly, EPA believes that design or equipment standards on federally regulated equipment (locomotive and rail cars) are preempted. Design or equipment standards on other pieces of equipment, such as retarders or cribbing machines, are not preempted. Similarly, design standards on facilities not federally regulated are not preempted, even though locmotives and rail cars may operate there, because they do not require the modification of locomotives or rail cars. An example of this type of regulation would be a local ordinance requiring that noise barriers be installed along the rights of way running through that community.

Use, Operation, or Movement Controls

A reduction in community noise impact can be achieved if the manner, time, or frequency of use of a noise source is controlled. Clearly, such controls may be adopted and enforced with respect to equipment that EPA has not regulated. However, with respect to federally regulated equipment (locomotives and rail cars), such controls may not be imposed unless the Administrator has determined that such state or local regulation is necessitated by special local conditions and that it is not in conflict with EPA regulations. A use restriction on railroad facilities may be subject to such determination also if, in order to comply, the railroad must control the use, operation, or movement of federally regulated equipment within that facility. The determinations called for will be made by EPA in accordance with procedures now being developed.

Receiving Land Use Standards

Receiving land use standards are to be distinguished from property line standards on the basis that property line standards focus on the identity of the noise source, such as railroad yards or rights of way, whereas receiving land use standards focus on the identity of the property receiving the sound, such as schools, hospitals or residential property. Obviously, a community is not preempted from enacting such standards simply because it has a railroad within its jurisdiction. However, it is possible that a standard that says, for example, that no school may be exposed to exterior noise levels in excess of 55 dBA may require modification of locomotives or rail cars in a community in which schools are close to the right of way of a railroad. Whether, or to what extent, such regulations are preempted, will be determined by EPA in accordance with procedures being developed.

Section 2

SUMMARY OF WHAT THE REGULATION REQUIRES

APPLICATION OF BEST AVAILABLE TECHNOLOGY TAKING INTO ACCOUNT THE COST OF COMPLIANCE

Section 17 of the Noise Control Act requires that the regulation . . . "reflect the degree of noise reduction achievable through the application of the best available technology, taking into account the cost of compliance." For this purpose, best available technology is defined as that noise abatement technology available for application to railroads that produces meaningful reduction in the noise produced by railroads. Available is further defined to include:

- Technology that has been demonstrated and that is currently known to be feasible.
- Technology for which there will be a production capacity to produce the estimated number of parts required in reasonable time to allow for distribution and installation prior to the effective date of the regulation.
- Technology that is compatible with all safety regulations and that takes into account operational consideration, including maintenance, and other pollution control equipment

The cost of compliance, as used in the regulation, means the cost of identifying what action must be taken to meet the specified noise emission levels, the cost of taking that action, and any additional cost of operations and maintenance caused by that action. The cost for future replacement parts was also considered.

As discussed in Section 5 of this report, the only source of railroad noise proposed to be regulated by the Federal government at the present time is trains. Therefore, the following pages will discuss the noise abatement technology for trains, in consonance with the statutory requirements and interpretation just presented.

Train noise is composed of locomotive noise and car noise. The latter is primarily the result of wheel/rail interaction and wheel/retarder interaction. The locomotive noise is composed of noise from the engine exhaust, casing, cooling fans, and wheel/rail interaction. The technology for treating casing, fan, and wheel/rail noise is in the early development and research stages and thus not available for application at this time. However, the technology for exhaust silencing has been found to be available. Further, the locomotive noise is dominated by the engine exhaust noise and, therefore, the application of exhaust muffler technology is the most effective initial step to require for locomotive noise abatement. The consequences of establishing a standard that would require modification of engine casing, cooling fans, and wheel/rail interaction have not been assessed in detail. It is clear, however, that without first reducing exhaust noise, treatment of these components would result in little or no perceptible noise reduction.

LEVELS OF TRAIN NOISE CONTROL

In this discussion, noise levels that can be reasonably attained with appropriate maintenance of existing equipment and by the application of the best available technology are discussed for locomotives both at rest and in motion and for railcars in motion.

Locomotive Noise–Vehicle at Rest

As discussed in Section 5, locomotive noise is dominated by the exhaust of diesel engines, which operate at eight possible speed and power output levels. One way to attain environmental noise control would be to limit the noise at all of these throttle settings; however, this could lead to combersome enforcement practices. For ease of enforcement, permissible noise could be specified at the throttle setting with the most noise–throttle 8. However, this approach may lead muffler manufacturers to design mufflers that are tuned to the engine speed corresponding to that throttle setting. Such mufflers could be effective at the design setting and ineffective at other settings. Obviously, this would defeat the purpose of a locomotive regulation.

A compromise solution is to control locomotive noise at two conditions: idle and full power. Idle and full power apply to frequently used throttle settings. Specifying two throttle settings will probably preclude the design of specially tuned mufflers. Rather, it is anticipated that mufflers that will be uniformly effective at all throttle settings will result.

Although it is unrealistic to assume that mufflers can be designed, fabricated, and installed on all new locomotives as soon as a regulation is promulgated, it is not unreasonable to hold noise at the level of existing, well-maintained equipment. Data, for locomotives at throttle setting 8 indicate that almost no locomotives exceed 93 dBA at 100 ft. Likewise, data indicated that locomotives at idle can be expected not to emit more than 73 dBA at 100 ft. Accordingly, the following levels have been identified as indicative of present noise emissions:

• Idle	73
• Overall Maximum	93

Section 5 indicates that mufflers capable of reducing exhaust noise by 10 dBA are feasible. Depending upon the relative contribution of the exhaust noise to the dominant sources of locomotive noise, this reduction may produce a 4 to 8 dBA reduction in the total noise (see Table 5-5). It is believed that the noisier locomotives have a higher exhaust noise component and, therefore, may achieve greater overall reduction in total noise by reducing exhaust noise. Based on the considerations of available empirical data, at throttle settings other than idle, an overall noise reduction of 6 dBA for the noisier locomotives seems reasonable. However, the EPA received further data in response to the docket, which indicated that a number of locomotives would be incapable of compliance with the proposed 67-dBA idle standard through the application of muffler technology alone, due to the presence of excessively high levels of structurally radiated noise at idle. As the result of an analysis of all pertinent data dealing with the noise levels and the availability of technology for compliance, the permissible long term idle noise level has been raised 3 dBA. Accordingly, the application of an exhaust muffler can be expected to permit all locomotives to achieve the following levels:

• Idle	70 dBA
• Overall Maximum	87 dBA

The exhaust noise is primarily a function of the diesel engine horsepower and the method of engine aspiration. Rootes-blown engines would have higher exhaust noise than an equal size turbocharged engine. Also, a larger engine has higher exhaust noise than a smaller engine if the aspiration is the same.

However, the larger engines are generally turbocharged, while the small engines are Rootes-blown. This leads to a partial cancellation of the effect of power and aspiration on the exhaust noise. It may be feasible in the future to establish separate standards for different types of locomotives, depending upon power or method of aspiration. This is not possible with the present data, however.

Section 5 also shows that muffler manufacturers could supply the needed hardware within the 4 years allotted for design, development, and testing.

Locomotive Noise–Vehicle in Motion

In addition to the stationary locomotive standard a passby standard that relates directly to the manner in which locomotives operate in the environment is also desirable. Such a standard also could be a useful tool for adoption and enforcement by local and state governments.

Based on available train passby data (see Figure 5-3) 96 dBA measured at 100 feet is achievable and represents the best maintenance practice level for current locomotive noise emissions. As just discussed, a reduction in overall locomotive noise of 6 dBA for the noisier locomotive through proper muffler application is considered reasonable. Therefore, using the same projected design, development, and testing times mentioned above, a 90 dBA noise emission level measured at 100 feet for all newly manufactured locomotives during a passby test would be required in 4 years.

Rail Car Noise–Vehicles in Motion on Line

Figure 5-8 shows that at a given speed, rail car noise ranges ± 5 dBA above or below a mean value. At 45 mph, the mean is approximately 83 dBA. At 60 mph, the mean is approximately 88 dBA. As such, the following Best-Maintenance-Practice-Standard measured at a 100-ft distance for rail cars in motion is considered appropriate:

Rail Car Speed (v) *mps*	*Noise Level* *dBA*
$V \leqslant 45$	88
$V > 45$	93

Rail Car Noise–Vehicles in Motion in Yards

As discussed in Section 5, a rail car passage through a retarder causes the emission of noise levels as high as 120 dBA. Further discussed, are five possible methods of retarder noise control that might conceivably be employed individually or in concert. With such information, it might be argued that a *status quo* level of 120 dBA may be appropriate at this time and could be subsequently reduced to approximately 80 dBA as the technology of retarder noise control advances over the next few years. At this time, however, it is the Agency position that retarder noise is an element of fixed facility railroad yard noise that, as such, can best be controlled by measures that do not in themselves affect the movement of trains and therefore do not require national uniformity of treatment. Such noise control measures might include, for example, the erection of noise barriers.

The Agency study of railroad yard noise indicates that concern for noise from railroad yards is more local than national. This is due in large part to the location of the number of yards in non-urban areas and the relatively small number of hump yards (130). Accordingly, the establishment of a uniform national standard could potentially incur significant costs to the railroads with only limited environmental impact resulting in terms of the population relieved from undesirable noise levels.

REVISION OF THE PROPOSED REGULATION PRIOR TO PROMULGATION

The Interstate Rail Carrier Noise Emission Regulations, which are now being promulgated, incorporate several changes from the proposed regulation published on July 3, 1974. These changes are based upon the public comments received and upon the continuing study of rail carrier noise by the Agency. In all but four instances, such changes were not substantial they are only intended to further clarify the intent of the regulations.

The first substantive change is that the restricted coverage of the long term locomotive standard for both stationary and moving conditions will now apply only to those locomotives newly manufactured, effective 4 years after the promulgation of the final regulation. Accordingly, the retrofit provision as originally proposed has been deleted from the final regulation.

A number of factors influenced the EPA decision to delete the retrofit requirement. Several docket entries contained economic and technological data that conflict significantly with the EPA data that appears in the Background Document. The principal areas of conflict involve disparities in determination of the best available technology as it exists today and the resultant costs of its application. There is a further complicating factor in that the available space configurations existant within many locomotives have been altered over the years due to the addition and modification of various locomotive components such as dynamic braking systems and spark arresters. As a result of this practice, there are numerous and diverse locomotive configurations, each possessing its own specific peculiarities that must be accounted for in a retrofit program. The implications of this diversity of locomotive configurations and the accompanying disagreement concerning available technology and the cost of its application (i.e., labor rates, capital costs of new facilities, etc.) have given rise to cost of compliance figures ranging from the original EPA estimates of $80 to $100 million to industry estimates approximating $400 to $800 million.

Although the generation of additional information concerning the availability of technology may allow the Agency to reconcile these widely varying retrofit cost estimates, the collection of such data would be a costly and time consuming process that may produce a retrofit cost estimate remaining substantially high relative to the public health and welfare benefits that would result. For these reasons, the Agency has decided to remove the retrofit requirement from the regulation being promulgated herein. Acknowledging the uncertainties that currently accompany the retrofit provision, the Agency may continue to consider the retrofit issue and may promulgate a retrofit requirement if further information indicates that the technology is available and that retrofit compliance costs are reasonable relative to the health and welfare benefits to be accrued.

The second substantive change to the regulation involves modifying the proposed locomotive idle standard by increasing allowable noise emissions from the proposed 67 dBA to 70 dBA at 100 ft. This change was made to accommodate new data that demonstrated that certain locomotive models appear to be incapable of compliance with a 67-dBA standard through the application of muffler technology alone, due to the dominant influence of structurally radiated noise during idle operation

The third substantive change to the regulation is that the effective dates of the initial standards have been changed from 270 days to 365 days from the date of promulgation in response to requests by the DOT.

The final substantive change to the regulation is the incorporation of additional measurement criteria into the standards as a separate Subpart C of the regulation. The noise emission standards specified in the Agency regulations must be fully and definitively specified so that there is no question as to the EPA standard being promulgated. Accordingly, measurement criteria containing those conditions and parameters necessary for the consistent and accurate measurement of the sound levels specified have been included in the final regulation.

Those changes made to clarify the intent of the regulations and the reasons therefore, are:

- Section 201.1 Definitions

  The definition of "sound level" was changed slightly to be consistent with the definition of that term as used in the document, *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*," issued by the Environmental Protection Agency in March 1974.

  "Fast meter response" has been expanded for clarity.

  "Interstate commerce" has been modified to ensure that any questions as to its scope would be resolved by reference to Section 203(a) of the Interstate Commerce Act, consistent with the reference to that Act in Section 17(b) of the Noise Control Act.

  "Person" has been deleted since the word is no longer used in subpart B of the regulation.

  "Sound pressure level" has been deleted since the words are no longer used in subpart B of the regulation

  "Special track work" has been added in order to clarify the meaning of the term as used in the find regulation.

  "Locomotive" has been expanded to include self-propelled rail passenger vehicles.

  "Special Purpose Equipment" has been added to clarify the meaning of the term as used in the final regulation.

  "Retarder" has been deleted since the word is no longer used in subpart B of the regulation.

  "Self load" has been deleted since the term is no longer used in subpart B of the regulation.

  "Idle" has been expanded to clarify the meaning of the term as used in the regulation.

  "dBA" has been modified slightly to specify the reference pressure of 20 micropascals.

- Section 201.10 Applicability

  This section has been modified slightly to exclude the application of Section 201.11(a) and (b) to gas turbine powered locomotives and any locomotive type which cannot be connected by any standard method to a load cell, and to more clearly specify the exclusion of intra-urban mass transit systems in terms consistent with the definition of "carrier" cited in the Act. In addition, the wording in the section has been modified to more clearly include the application of the standards to refrigeration and airconditioning units on locomotives and rail cars. Finally, the express exclusion of the applicability of the standards to railroad yards, shops, rights-of-way, or any other railroad equipment or facility not specified in the regulation has been deleted as unnecessary.

- Section 201.11 and 201.12 Standards for Locomotive Operation

  Under Stationary and Moving Conditions, Respectively.

  In addition to the applicability and effective date changes previously described, the reference to measurement site surface has been deleted and replaced by language referencing the measurement criteria in Subpart C of the regulation. Also the phrase "or the equivalent thereof" in reference to a load cell has been deleted.

- Section 201.12 Standard for Rail Car Operations

  Track curvature requirements for measurement sites identical to those specified in Section 201.12 for locomotives were incorporated into this section in addition to identical language referencing the measurement criteria of Subpart C as used in Section 201.12 and 201.11 for locomotive test sites. Also, the language in the section was modified slightly so as to to restrict compliance measurements to track free of special track work or bridges or trestles. The change in the effective date previously described also applies to this section.

NOISE EMISSION STANDARDS INTERSTATE RAIL CARRIER NOISE REGULATION

- Rail Cars

  Best Maintenance Practice Standards; Effective, 365 Days:

  @ Speeds: $\leq$ 45 mph: 88 dBA
  @ Speeds: $>$ 45 mph: 93 dBA

- Locomotives

  a. Best Maintenance Practice Standards; Effective, 365 Days:

     (1) Stationary:

        (a) Idle: 73 dBA
        (b) Other Throttle: 93 dBA

     (2) Moving: 96 dBA

  b. Four year Newly Manufactured Standards:

     (1) Stationary:

        (a) Idle: 70 dBA
        (b) Other Throttle: 87 dBA

     (2) Moving: 90 dBA

Section 3

DATA BASE FOR THE REGULATION

The program for compiling data on train noise began with a search for existing data. By compiling the existing data, it was possible to avoid repeating the few measurements completed by others, and the limitations of the existing data indicated what measurements needed to be made to extend the data. Technical journals were searched for reports of pertinent measurements. Published accounts of measurements in Europe and Asia were considered along with the accounts of measurements in the United States and Canada.

Much of the needed data was obtained by the EPA Regional Offices and under contract by acoustical consultants. Some unpublished accounts of measurements and proceedings of appropriate seminars were obtained through informal communication with members of the acoustics community. Leaders in the engineering departments of the two remaining locomotive manufacturers Electro-Motive Division of General Motors (EMD) and General Electric Corp. (GE) were also interviewed to ascertain the extent of their data files, as well as to determine what problems may be created by attempts to control locomotive noise. At a meeting hosted by the Association of American Railroads, EMD, and GE engineers reported measurements of locomotive noise and discussed some possible effects of locomotive noise controls. Three leading muffler manufacturers (Donaldson, Harco Engineering, and Universal Silencer) were contacted to evaluate the feasibility and the impact of fitting locomotives with exhaust mufflers.

Railroad company personnel who worked in various capacities at various levels were contacted to determine the mix of equipment used by railroads, the configurations of properties and equipment, the scheduling of operations, and the modes of operation. In particular, yard masters, yard superintendents, or engineering personnel were contacted to obtain information about yard configuration, layout, and equipment. Railroad personnel were asked for information related to schedules and speeds of trains. The railroad companies that participated are listed in the references for this report.

To resolve questions raised in the docket comment to the Notice of Proposed Rule Making, the Agency engaged in further study of railroad noise, focusing on the further definition of available technology and attendant costs that would be incurred during the implementation of a locomotive retrofit program. In addition to information received from the docket comments and from additional contractor effort, the Agency was the recipient of a gratis study conducted by the General Motors Corporation Electromotive Division that attempted to identify the costs involved in the retrofit of the major EMD locomotive models currently in operation. The results of this study have been included as Appendices E and F to this document.

The sources of all information and data cited in this document are listed in the Reference Section at the end of this report.

Section 4

THE RAILROAD INDUSTRY

ECONOMIC STATUS

There are currently 72 Class I railroads in the U.S.* These tend to break down into two groups: large transportation companies such as the Union Pacific or the Penn Central and railroads owned by large industrial firms such as U.S. Steel. The latter roads primarily provide transportation services to the parent company. Since railroads are regulated by the Interstate Commerce Commission (ICC), the degree of competition is also regulated. The size of the firms has in many cases been determined by whether the ICC has allowed or disapproved mergers. Most large roads have grown through mergers. In addition, the favorable financial positions of some roads have resulted from their non-transportation activities.

The total tonnage of freight moved in the U.S. has been rising over time, but the transportation sector of the economy has declined in relative importance. In 1950, 5.6 percent of national income originated in the transportation sector. By 1968, this figure declined to 3.8 percent and has remained at about that level. This trend reflects the higher relative growth rates in those industries that require a smaller transportation input.

The rail industry has declined more rapidly than the transportation sector as a whole. In 1950, the rail sector constituted 53 percent of the national income originating in the transportation sector. By 1968 it had declined to 25.8 percent of the transportation sector and has remained relatively stable since then. Table 4-1 summarizes these statistics.**

Accompanying the decline in the rail sector's share in national income originating in the transportation sector, the proportion of total freight hauled by rail has declined. In 1940, the railroads hauled 63.2 percent of all freight, dropping to 44.7 percent by 1960 and to 39.9 percent by 1970. Motor carriers and oil pipelines have rapidly increased their share during this period. Air freight has increased more rapidly than either motor carriers or pipelines, but it accounts for only 0.18 percent of total freight. In spite of the decreasing proportion of shipments by rail, railroads still produce more ton-miles of freight transportation than any other single mode, the total volume of freight hauled by rail having increased from 411.8 billion ton-miles in 1940 to 594.9 in 1960, to 768.0 in 1970, and to an estimated 855 in 1974. Table 4-2 summarizes these trends.

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*Class I railroads are those having annual revenues of $5 million or more. They account for 99 percent of the national freight traffic.

**Unless otherwise stated, the data presented in Tables 4-1 through 4-6 were obtained from the Statistical Abstract of the United States (1971) and (1972).

TABLE 4-1
NATIONAL INCOME ORIGINATING IN THE TRANSPORTATION AND RAIL SECTORS
($ In Billions)

Year	National Income	Transportation	Transportation as % of National Income	Rail	Rail as % of Transportation
1950	$241.1	$13.4	5.6%	$7.1	53.0%
1960	414.5	18.2	4.5	6.7	36.8
1965	564.3	23.2	4.1	7.0	30.2
1968	712.7	27.1	3.8	7.0	25.8
1969	769.5	29.2	3.8	7.4	25.3
1970	795.9	29.5	3.7	7.2	24.4

TABLE 4-2
INTERCITY FREIGHT (In Billions of Ton-Miles)

Year	Total Freight Volume in 10^9 Ton-Miles	Rail Freight in 10^9 Ton-Miles	Rail %	Motor Vehicles %	Oil Pipelines %	Air %	Inland Water %
1940	651.2	411.8	63.2	9.5	9.1	.002	18.1
1956	1376.3	677.0	49.2	18.1	16.7	.04	16.0
1960	1330.0	594.9	44.7	21.5	17.2	.06	16.6
1965	1651.0	721.1	43.7	21.8	18.6	.12	15.9
1968	1838.7	765.8	41.2	21.6	21.3	.16	15.9
1969	1898.0	780.0	41.1	21.3	21.7	.17	15.8
1970	1921.0	768	39.9	21.44	22.4	.18	15.98

Rail passenger service declined from 6.4 percent of intercity travel in 1950 to less than 0.1 percent in 1970. The real impact of railroads on the national economy is in terms of freight rather than passengers. The decline of the rail industry share of the transportation sector is less dramatic when passenger service (air, local, suburban, and highway) is eliminated from calculations. Table 4-3 gives the transportation sector percentage contributions to national income, less the passenger sectors just mentioned, and the rail industry's percentage of the transportation sector.

TABLE 4-3

PERCENT OF NATIONAL INCOME ORIGINATING IN THE TRANSPORTATION SECTOR (LESS AIRLINE AND LOCAL SUBURBAN AND HIGHWAY PASSENGERS) AND THE RAIL SECTOR AS A PERCENT OF TRANSPORTATION

Year	Transportation* (Adjusted) as % of National Income	Railroads as % of Transportation (Adjusted)
1950	4.8%	61.7%
1960	3.7	44.1
1965	3.3	37.6
1968	3.0	33.0
1969	3.0	32.3
1970	2.9	Not Available

*Transportation minus air carriers and local suburban and highway passengers.

From comparison of Table 4-1 and 4-3, it can be seen that the freight sector has declined more rapidly than the total transportation sector. It can also be seen that the railroads' decline is somewhat less dramatic in terms of freight alone than in terms of both freight and passenger service.

EMPLOYMENT

The railroads' importance as a source of employment within the economy has decreased along with their share of the nation's transportation output. In 1950, the railroads accounted for 2.7 percent of all employees in nonagricultural establishments. By 1970, this had fallen to less than 1.0 percent. Not only has the relative importance of railroads declined, the absolute level of employment from 1950 to 1970 decreased by over 50 percent as shown in Table 4-4.

Wages in the rail sector have consistently been above the average of all manufacturing employees, and this differential has increased over the years. In 1950, the average hourly compensation in the rail sector was $1.60 which was 110 percent of the average hourly compensation in manufacturing. In 1968 average compensation was $3.54, or 118 percent of that in manufacturing. By 1971, rail compensation had increased to 126 percent of the average compensation in the manufacturing sector.

TABLE 4-4
EMPLOYMENT IN THE RAIL INDUSTRY RELATIVE TO THE NATIONAL ECONOMY

Year	National Employees in All Nonagricultural Establishments (1000)	Railroad Employment (1000)	Railroad as % of National
1950	45,222	1220	2.7%
1960	54,234	780	1.4
1965	60,815	640	1.1
1968	67,915	591	.9
1969	70,274	578	.8
1970	70,664	566	.8

Increases in wage rates in the rail sector have been greater than the increases in the wage rates in the manufacturing sector. Using 1967 as the base (=100), the index of wage rates in manufacturing in 1970 was 121.6, while the rail industry index was 125.6. Over the same period, the increase in productivity in the rail industry has been less than productivity increases in manufacturing. In 1970, the index of output for all railroad employees was 109.9*, while in manufacturing it was 111.6 (using a 1967 base of 100). Table 4-5 summarizes the wage and productivity data.

TABLE 4-5
INDEX OF OUTPUT PER MAN HOUR AND WAGES
(1967 = 100)

Year	Rail Wage	Manufacturing Wage	Rail Productivity	Manufacturing Productivity
1950	41.5	44.7	42.0	64.4
1960	74.3	76.6	63.6	79.9
1965	88.9	91.2	90.8	98.3
1968	106.3	107.1	104.4	104.7
1969	113.6	113.9	109.3	107.7
1970	125.6	121.6	109.9	116.6

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*Computed on the basis of revenue per man-hour.

The fact that productivity increases have not kept pace with wage rate increases indicates that unit labor costs are rising.

In the years since 1970, wages in the rail industry have, as in most industries, increased rapidly. The index of wages in 1971 was 136.8; in 1972 , 136.8; and in 1973, 165.4 (estimated).

HEALTH AND GROWTH OF THE INDUSTRY

Health of the Industry

There are a number of measures one might use to judge the health or financial stability of the rail industry. Two of these are the rate of return on stockholder equity and the percent of revenue carried through to net operating revenue. Shareholder equity is the excess of assets over liabilities, which is equal to the book value of capital stock and surplus.

In 1971, the rate of return on stockholder equity for all manufacturing firms was 10.8 percent. The rates of returns in some selected industries are as follows:

• Instruments, photo goods, etc.	15.8%
• Glass Products	11.1%
• Distilling	9.9%
• Nonferrous metals	5.2%

The return for the total transportation sector was 3.1 percent. Railroads showed a 2.1 percent on stockholder equity, slightly above the airlines' 2.0 percent.

The rate of return on stockholder equity increased from 1.3 percent in 1971 to 3.0 percent in 1972. The use of industry data, however, tends to give a misleading impression of the industry.*

The Eastern District had a negative rate of return for the three years from 1970 to 1972, while both the Southern and Western Districts had positive and increasing rates of returns. The Southern District showed an increase from 5.2 percent to 6.1 percent and the West from 3.7 to 5.1 percent. The rates of returns in these districts are well above the 3.1 percent for total transportation and are about equal to the textile and paper industries.

These trends indicate that the problem in the rail industry is not with all districts but primarily with roads in the Eastern District. Using operating ratios** as the measure of financial stability, one draws the same conclusions.

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*Because the railroads use a nonstandard accounting procedure (the so-called betterment technique), the rate of return is low relative to what it would be if they used a procedure comparable to those used in the nonregulated sector.

**Operating ratio equals operation expenses divided by operating revenues.

The historical trends in the profitability of the industry can be measured by the percent of gross revenue carried through to net operating income before Federal income taxes. This measure is similar to the rate of return on sales before taxes. For the industry as a whole, the percent of gross revenue carried through has been declining. This is also true of each district, with the Eastern being the worst. Table 4-6 summarizes these trends.

TABLE 4-6
PERCENT OF GROSS REVENUE CARRIED THROUGH TO NET OPERATING INCOME BEFORE FEDERAL INCOME TAXES

Year	All Class I RR's	Southern District	Eastern District	Western District
1950	17.3%	20.1%	12.0%	19.8%
1960	8.3	10.7	2.1	10.0
1965	11.0	12.1	10.0	11.6
1968	6.9	11.0	3.7	8.4
1969	6.6	12.1	2.7	8.0
1970	4.2	11.8	Nil	7.7
1971	4.0	10.3	0.5	7.2

The performances of the Southern and Western Districts are much better than the Eastern. In fact, one could conclude that compared with nonregulated industries such as steel, the Southern and Western roads are reasonably good performers. Compared with other regulated industries, such as public utilities (10.5 percent return on stockholder equity) and telephone and telegraph companies (9.5 percent return on stockholder equity), the railroad rate of return is low. One point that should be made is that railroads follow a betterment accounting procedure, which tends to overstate the value of their assets. We have not attempted to adjust rate of return in the rail industry to reflect this.

The historical decline in the profitability of railroads came as a result of a decrease in the relative importance of high-weight, low-value cargo, which has traditionally been handled by rail. The increased competition from motor carriers and pipelines has further reduced the relative importance of railroads. Federal and state funding of highways has improved the competitive position of trucks and has led to the diversion of high-valued freight to motor carriers.

In 1935, when motor carriers came under Interstate Commerce Commission regulation, the value-of-service rate structure applied to railroads was also applied to motor carriers. (The value-of-service rate-making policy was originally applied to railroads to favor agricultural products.

Under value-of-service rates, low-valued products have a lower rate per ton-mile than do high-value products.*) This measure reduced intermodal price competition and, in fact, gave an advantage to trucks in carrying high-valued freight when they could give faster service. Railroads were unable to lower prices on this type of freight, which could have offset the faster service offered by trucks.

The decline of some manufacturing industries in the East has led to a more intense financial crisis among eastern roads. Also, the capital stock of these railroads tends to be older than that of the other roads. They spend a larger portion of total cost on yard switching than do either Southern or Western roads, due to shorter hauls and a larger number of interchanges among roads. Since shippers pay for movement from one point to another (i.e., rate per mile), the competitive position of railroads tends to be diminished if these nonline-haul expenses rise. The greater yard-switching results in having rail cars sit in switching yards waiting for a train to be made up, thus resulting in longer time in transit and higher comparative costs.

Growth of the Industry

In projecting growth rates in any industry, it is assumed that historical trends and relationships will continue to hold in the future to some extent. If these relationships do continue, then rail freight can be projected based on projection of other figures. For example, rail freight service on the basis of population or gross national product can be projected. If the population continues to consume similar commodities, if these commodities move by the same modes of transporation, and if increases in income are ignored, then projections based on accurate population projections will be valid.

The number of ton-miles of railroad freight per capita in the U.S. has remained stable over recent years. It was 3.73 in 1965, 3.77 in 1968, and 3.75 in 1970. Given this stability, reasonable short-run projections based on population growth may be made. Based on the population projections for the U.S., about a 1.0 percent annual increase over the next 5 years is estimated. This would project an increase from 768 billion ton-miles in 1970 to about 822 billion ton-miles in 1975. This projection falls somewhat short of the estimated 855 billion [42] ton-miles of freight actually hauled in 1974. This difference is largely attributable to a gradually increasing efficiency in the operation and utilization of railroad equipments and facilities, as well as periods of increased coal and grain traffic during the past few years. However, exclusive of any dramatic improvements in railroad technology or operations, or substantial fluctuations in the types and amounts of commodities available for transport, the 1.0 percent figure seems to provide a reasonable projection of short run growth.

One other factor that may accelerate the growth of demand for rail transporation services is that rail movement uses less energy than other forms of freight movement. A ton-mile of freight moved by rail requires 750 BTU, while pipelines require 1850, trucks 2400, and air freight 63,000. The only mode of freight movement more efficient (in terms of energy) than rail is water, which requires 500 BTU [41].

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*These points are examined in an article by R. H. Harbeson in the 1969 *Journal of Law and Economics*, pp. 321-338.

The rail industry contribution to national income has remained relatively constant from 1968 to 1970 at about 1.0 percent. The long-run rate of growth in GNP has been about 3.5 percent. Again, under the assumption that these historical relationships hold, the long-run growth should be around 3.5 percent.

Energy may come to be an important factor and may cause some short run traffic variations, but it seems unlikely that rail freight will increase more rapidly than the growth in national income in the long-run. The factor mitigating a more rapid increase is that consumption patterns have continued to move toward more services and fewer manufactured products. This means a smaller transportation input. In addition, rising interest rates and greater product differentiation have caused shippers to be increasingly concerned with time in transit. The railroads' real advantage is in rates, not speed. However, the advent of transporting entire truck trailers by rail has aided in substantially reducing delivery time where this is practiced.

Section 5

RAILROAD NOISE SOURCES

OVERVIEW OF THE PROBLEM

Noise is generated by railroad operations in two basic locations: in yards and on lines. In railroad yards, trains are broken down and assembled and maintenance is performed. Line operations involve the sustained motion of locomotives pulling a string of cars over tracks.

The hump yard is an efficient system for disengaging cars from incoming trains and assembling them into appropriate outgoing trains. A locomotive pushes a string of cars up a small hill, known as a hump, allowing each car to roll individually down the other side through a series of switches onto the appropriate track, where a train is being assembled. As each car rolls down the hump, it is first slowed by the master retarder.

The slowing, or retarding, is accomplished by metal beams that squeeze the wheel of the rail car. After the cars leave the master retarder, they coast into a switching area that contains many tracks. As each car is switched onto a particular track, it is slowed by a group retarder. After a car moves out of a group retarder, it is switched onto one of many (approximately 50) tracks in the classification area, where the car collides with another car.

The collision causes the cars to couple, forming a train. In some yards, the first car that moves into the classification area along a particular track is stopped by an inert retarder, so called because the retaining beam is spring-loaded and requires no external operation. Inert retarders differ from the master and group retarders, which are controlled continuously by an operator or automatically by a computer.

All three of the retarding processes just described produce noise. When the beam of a master or group retarder rubs against the wheels, a loud squeal is often generated. The most significant noise generated by inert retarders occurs when a string of cars is pulled through. If the inert retarders are short and exert small forces, they may generate noise that is negligible compared with the noise generated by the group retarders. Some yards are equipped with inert retarders that can be manually or automatically released when a string of cars is pulled through them, thereby preventing retarder squeal. There are no inert retarders in some yards, so an individual brakeman must ride some cars and brake them manually.

Noise is also produced when cars couple in the classification area of the yard. The impact points, and thus the origins of the noise, are scattered over the classification yard. The noise is impulsive, and sometimes it is followed by a thunderlike rumble audible for several seconds after the impact.

Locomotive engines generate noise as the locomotives move around or pass through yards. When the locomotives are not in use, their engines are often allowed to idle continuously (even overnight), which also results in significant noise. When the locomotives are in motion, their horns, whistles, and bells may produce noise for warning purposes.

Some noise originates in the yard shops, where locomotives and cars are repaired and maintained. Power tools and ventilation fans represent such sources. However, the most readily identifiable sources of shop noise are the locomotives themselves when undergoing testing.

Most yards are equipped with a number of loudspeakers used for conveying verbal instructions and warning sounds to workers in the yard. The speakers are scattered about the yard, and a given speaker issues sound on an unpredictable schedule.

Line, or wayside noise--the noise in communities from passing trains--is produced by many high-noise sources. The locomotive engine and its components, such as exhaust systems and cooling fans, and the interaction of railroad car wheels with rails results in significant noise.

Wheel/rail noise is caused principally by impact at rail joints, giving rise to the familiar clickety-clack, and by small-scale wheel and rail roughness. A severe form of wheel roughness that generates high noise levels is caused by flat spots developed during hard braking. Also, wheels squeal on sharp curves and generate noise by flange-rubbing on moderate curves. The operation of such auxiliaries as refrigeration equipment also contributes to the overall noise level. Horns or whistles are sounded at crossings and are significantly louder than the other wayside noises. In addition, some crossings are equipped with stationary bells that sound before and during the passage of trains.

The remainder of Section 5 treats each of the noise sources mentioned separately and in as much detail as the state-of-the-art allows. Included in the discussion of each source is a description of abatement techniques.

CONSIDERATION OF RAILROAD NOISE SOURCES FOR FEDERAL REGULATIONS

The EPA has studied the operations of rail carriers engaged in interstate commerce by rail and recognizes that such operations are imbedded in every corner of the nation at thousands of locations and along hundreds of thousands of miles of right-of-way. The nature and magnitude of the noises produced by the many types of facilities and equipment utilized in these operations differ greatly, and their impact on the environment varies widely depending on whether they occur, for example, in a desert or adjacent to a residential area.

The Agency concludes that the control of certain of these noise sources, such as fixed facilities, or equipment used infrequently or primarily in one location, is best handled by the state and local authorities, rather than by the Federal government. State and local authorities are believed in this case to be better able to consider local circumstances in applying such measures as the addition of noise barriers or sound insulation to particular facilities or the positioning of noisy equipment within these facilities as far as possible from noise-sensitive areas. Further, and more importantly, the EPA did not find during its analysis, and has not received from rail carriers, any information identifying situations in which lack of uniform state and local laws regarding these facilities and equipment has imposed any significant burden on interstate commerce.

The Administrator has considered the following broad categories of railroad noise sources, to identify those types of equipment and facilities requiring national uniformity of treatment through Federal noise regulations to facilitate interstate commerce.

Office Buildings

Many, if not all, surface carriers engaged in interstate commerce by railroad own and operate office buildings. These buildings are technically facilities of the carriers. Like all office buildings they may emit noise from their air conditioning and mechanical equipment. But since each building is permanently located in only one jurisdiction and is potentially subject only to its regulations, it is not affected in any significant way by the fact that different jurisdictions may impose different standards on noise emissions from the air conditioning and mechanical equipment of other buildings. At this time, there appears to be no need for national uniformity of treatment of these facilities, and they are therefore not covered by this regulation.

Repair and Maintenance Shops

Railroad repair and maintenance shops are similar in many ways to many nonrailroad industrial facilities, such as machine shops, foundries, and forges. All such facilities can reduce their noise impact on the surrounding community by a variety of measures including:

- Reducing noise emissions at the source
- Providing better sound insulation for their buildings
- Erecting noise barriers
- Buying more land to act as a noise buffer
- Scheduling noise operations at times when their impact will be least severe
- Moving noisy equipment to locations more remote from adjoining property.

Such detailed and highly localized environmental considerations are best handled by local authorities so long as they comply with the applicable restrictions concerning Federal preemption. Like office buildings, shops are permanently located in only one jurisdiction and thus are not potentially subject to differing or conflicting noise regulations of other jurisdictions. At this time, therefore, there appears to be no need for national uniformity of treatment of these facilities, and they are not covered by this regulation.

At times, railroad maintenance shops may contain major noise sources that do require national uniformity of treatment, such as locomotives. But the fact that some such individual noise sources within a shop may be subject to Federal noise emission regulations is irrelevant to the validity of state or local noise emission regulations applied to the shop as a whole. This is so as long as the state or local regulation of the shop can be reasonably complied with without physically affecting the federally regulated noise source within the shop (for example, by installing sound insulation in the shop building). This will be discussed further in the section on preemption.

Terminals, Marshalling Yards, Humping Yards, and Specifically Railroad Retarders

Like office buildings and shops, railroad terminals and yards are permanent installations normally subject to the environmental noise regulations of only one jurisdiction. The Agency has determined that such fixed facility railroad yard and terminal noise is best controlled at this time at the local level, employing measures that do not in themselves affect the movement of trains and therefore do not require national uniformity of treatment.

Local jurisdictions are familiar with the particular complexities of their community/railroad noise situation, and, as such, are in a position to exhibit greater sensitivity in prescribing practical and cost effective solutions to the local noise problem. Railroad yard facilities vary in size, shape, and special characteristics, and the noises produced there are diverse.

The EPA recognizes that the communities neighboring these yards and terminals are equally diverse, varying in land zoning and population density and distribution. As such, Federal regulation successfully producing substantial population health and welfare benefit at one locality may produce little or no such benefit at another locality. For example, the regulation of a railroad yard facility enveloped by a residential community would not achieve similar population health and welfare benefit when equally applied to a similar railroad yard facility existing within a large industrial complex. This subject is discussed in more detail in Appendices C and D of this document.

Additionally, the Agency study of railroad yard noise (inclusive of retarder noise) indicates that concern for noise from railroad yards, and retarders in particular, is apparently limited to certain localities and is not a national concern. This is due in large part to the location of a number of yards in non-urban areas and the relatively few existing retarder systems, approximately 120.

This local nature of the retarder noise problem further reduces the desirability of a Federally preemptive regulation. For example, in a situation in which a retarder yard is bordered on one side by a residential area and on all other sides by an unpopulated wooded area, a barrier could be beneficial to public health and welfare only if erected on that side of the retarder facing the residential area. Under such circumstances a community would receive insufficient health and welfare benefits to justify the costs incurred by a Federally preemptive regulation that mandates the installation of barrier walls on both sides of retarder mechanisms.

At the currently estimated materials cost of $70 to $100 per linear foot for barriers, barrier costs would run from $75,000 to $150,000 per railroad yard and from $9.6 to $19.1 million for the entire railroad industry. Maintenance and replacement costs, yard down time, and track modification costs have not been fully identified.

Expenditures should be assured of producing maximum benefits, and this may best be done through local regulation. Available space for installation of barriers, and safety hazards that might accrue, have not been identified and are peculiar to the particular characteristics of the individual railroad yards and, as such, may be best accounted for through local regulation.

A Federal regulation for conversion of inert retarders to retractable inert retarders would be subject to considerations similar to those discussed for the erection of barriers around active retarders. However, probable yard down time and installation and materials costs would be considerably greater for conversion to inert retractable retarders than for the erection of barriers. The EPA estimates that conversion to retractable inert retarders would cost $7,500 for each retarder, not including labor, yard down time, or maintenance costs. Applying a gross estimate of 20,000 such inert retarders nationally, estimated national conversion costs, exclusive of labor, down time, and operational costs, would be $150 million.

Although the EPA does not currently propose to regulate retarder noise, it does recommend that local jurisdictions establish regulations requiring railroads to utilize barrier technology where needed and where both practical and feasible. Further consideration may be given by the EPA to possibly providing future regulations requiring that new retarder installations be equipped with retractable inert retarders, computer control systems, retarder beam lubrication systems, or other available technical developments resulting in significant noise reduction from retarders as the need for such regulations is demonstrated relative to the costs involved and the availability of technology.

For reasons just outlined, the EPA does not presently propose to regulate railroad yard or retarder noise.

Like railroad maintenance shops, marshalling and humping yards contain some noise sources that are covered by the proposed regulations. As is discussed in greater detail in the section on preemption, a state or local noise regulation on a railroad terminal or yard is, in effect, a regulation on the federally regulated noise sources within the terminal or yard when it can be met only by physically altering the Federally regulated noise sources, or as otherwise specified in the preemption discussion.

Horns, Whistles, Bells, and Other Warning Devices

These noises are different in nature from most other types of railroad noise since they are created intentionally to convey information to the hearer instead of as unwanted byproducts of some other activity. Railroad horns, whistles, bells, etc., are regulated at the Federal and state levels as safety devices rather than as noise sources.

Federal safety regulations are confined to the inspection of such devices on locomotives so as to ensure that, if present, they are suitably located and in good working order (Safety Appliance Act, 45 USCA; 49 Code of Federal Regulation, 121, 234, 236, 428, 429). State regulations are oriented toward specifying the conditions of use of these devices and, for the most part, do not specify any maximum or minimum allowable noise level for them. A recent survey of the 48 contiguous states (See Appendix B) has revealed the following:

- At least 43 states require that trains must sound warning signals when approaching public crossings.
- Thirty-five of these states specify some minimum distance from a public crossing at which a train approaching that crossing may sound a warning signal.
- Three states specify a maximum distance from a public crossing at which a train approaching that crossing may sound a warning signal.
- Thirty-five states specify that these warning signals must be sounded until the train reaches the crossing.
- Three states specify that these warning signals must be sounded until the train completely clears the crossing.
- Sixteen states provide for exceptions to their regulations for trains operating in incorporated areas.
- At least two states provide for exceptions to their regulations for trains approaching public crossings that are equipped with satisfactory warning devices.

The EPA does recognize that a noise problem exists as to the use and extent of railroad warning devices and that regulatory action may be appropriate for controlling them. However, the Agency believes that the requisite regulation can best be considered and implemented by state and local authorities, who are better able to evaluate the particular local circumstances with respect to the nature and extent of the noise problem and the requisite safety considerations involved. Any comprehensive Federal regulation in this area could be overly diverse and cumbersome. The EPA encourages in this regard the interaction between local and state governments and the railroads directly concerned in solving the particular local noise problems associated with the use of such warning devices. However, if local authorities, after having first sought solutions with the railroads involved, have still not been able to resolve their problems, they are encouraged to then direct their concerns to the EPA for possible further Federal action.

EPA has determined that the use of such warning devices in and around railroad yards is not out of place due to the often heavy intermingling of workers and mobile equipment with locomotives and rail cars. Such use may, of course, be beyond the extent necessary to ensure safety, not only in railroad yards but wherever else railroad horns, bells, and whistles are used. The term overused, however, is relative to the particular circumstances surrounding such use: whether, for example, a railroad yard or rail-highway intersection is situated in a residential as opposed to an industrialized area. These situations are instances where the EPA recommendation for railroad and community interaction is at this time the most appropriate means of achieving effective warning device noise abatement.

EPA encourages alternate solutions to the routine use of acoustic warning devices at rail and road crossings. For example, the elimination of public grade level railroad crossings would do away with the source of the problem, the intersection of rail tracks and public thoroughfares. However, such a national program of elevating or depressing either the railroad line or the public thoroughfare at each crossing, solely for the purpose of the abatement of acoustic warning signal noise, is not considered appropriate. It should be seriously considered, though, in future public thoroughfare or railroad line construction programs for both safety and environmental noise reasons.

Warning gates, too, as suggested, would appear to be an effective safety alternative to acoustic warning signals. Specifying their use on a national basis, however, would be prohibitively expensive considering that costs range from $45,000 to $90,000 per unit. And with the extensive use of grade level crossings in the United States, Illinois, for example, having approximately 15,000 crossings without drop gates, the cost would be $675 million or more in that state alone.

Since acoustic warning devices do serve the interests of safety and can best be regulated at the local and state level for the reasons indicated, EPA does not propose to regulate railroad acoustic warning devices at this time.

Special Purpose Equipment

Examples of special purpose equipment that may be located on or operated from rail cars include:

- Ballast cribbing machines
- Ballast regulators
- Conditioners and scarifiers
- Bolt machines
- Brush cutters
- Compactors
- Concrete mixers

- Cranes and derricks
- Earth boring machines
- Electric welding machines
- Grinders
- Grouters
- Pile drivers
- Rail heaters
- Rail layers
- Sandblasters
- Snow Plows
- Spike drivers
- Sprayers and numerous other types of maintenance-of-way equipment.

The Agency realized that special purpose equipment such as that used for maintenance-of-way activities is essentially construction equipment and as such, may emit loud intermittent noise. Railroads may avoid noise problems by keeping routine maintenance activities to reasonable times. Local jurisdictions may easily regulate operation times for such equipment as long as exceptions are allowed for emergency use. For example, a community may wish to regulate the hours allowed for routine operation of spike driving equipment, but exception must be made for the operation of such equipment in the aftermath of a derailment, so tht interstate commerce would not be unduly impeded.

The small numbers of such equipment, their infrequency of use, and the relative ease with which viable local regulations may be instituted all tend to make a federally preemptive regulation overly expensive relative to the benefits received.

There has not been any indication that any cases currently exist in which non-uniform local or state regulation of special purpose equipment has unduly burdened those railroads so regulated. At this time the Agency does not believe that special purpose equipment requires national uniformity of treatment. However, the rail cars on which such special purpose equipment is located are included under the standards for rail car operations. The Agency continues to solicit notice of specific cases in which non-uniform local or state regulation of special purpose equipment has created a burden on interstate commerce. If, in the future, it appears that national uniformity of treatment of such equipment is appropriate, noise emission standards may be proposed.

Track and Right-of-Way Design

The standard promulgated for rail cars applies to the total noise produced by the operation of trains on track. As such, it is preemptive with respect to both rail cars and track. It reflects the noise level achievable by application of best maintenance standards to rail cars. Further reductions in noise levels are achievable through various track repairs and modifications. However, EPA has not fully identified the available technology or the applicable costs associated with such practices. In the future, the EPA may propose standards that would require their application.

However, some steps, such as the erection of noise barriers, can be taken to reduce noise emissions from railroad rights-of-way that do not in any way affect the operation of trains on the rights-of-way. State and local governments are better able than the Federal Government to determine if some noise-sensitive areas need such protection; and the existence of differing requirements for such measures in different areas does not at this time appear to impose any significant burden on interstate commerce. There is presently no need for national uniformity of treatment of such noise abatement techniques; and they are, therefore, not covered by the proposed regulations.

The Federal railroad noise regulations do preempt any local regulations that set noise emission standards or require use restriction on rail cars equipped with auxiliary power units, more specifically, mechanically refrigerated freight cars, and various auxiliary powered passenger-related cars.

The initial decision by the Agency was to regulate noise from all sources produced by rail cars while in motion only and to leave to state and local authorities the regulation of whatever noise is produced from rail cars while stationary. This decision was made because these noises are a problem only when such cars are parked near noise-sensitive areas (such noises being indistinguishable from other railroad car noises while the cars are in motion) and because it was felt that such localized problems could best be controlled by measures such as the relocation of those cars to less noise-sensitive areas.

The Agency was and continues to be cognizant of the extent of the problem that can be caused in specific instances by the continuous operation of the diesel or gasoline engines operating on such cars. Noise levels as high as 75 dBA at 15 meters (50 feet) are possible from refrigerator cars parked with their cooling systems running in marshalling and humping yards. Noise levels from such refrigerator cars can be even greater because such cars are often parked coupled together in large numbers. Additional data acquired by and supplied to the Agency has shown that the problem exists not only with refrigerator cars but also with various passenger-related cars such as dining cars, lounge cars, cafe-type cars, and others equipped with self-contained power units. Also, the abatement of such noise appears possible and, in certain instances, is now being accomplished through the use of existing muffler designs.

The Agency therefore may consider the possible promulgation of a regulation dealing with the noise produced by mechanically refrigerated freight cars and passenger cars equipped with auxiliary power equipment so as to reduce the impact of such noise when these cars are parked near noise-sensitive areas.

It should be noted that, in the regulation, the standard for rail car operations refers to the total noise generated and that the setting of emission standards on any element of that noise is preempted, whether the rail car is in motion or stationary. This Federal regulatory action does not, however, interfere with the ability of state and local governments to enact or enforce railroad yard noise emission regulations that require railroads to erect noise barriers. Nor does the regulation interfere with the ability of state and local governments to enact or enforce noise emission regulations that require the relocation of parked rail cars generating noise so long as that regulation is reviewed and approved by EPA pursuant to Section 17(c)(2) of the Act.

The Agency has not intended and does not intend that intra-urban mass transit systems be covered by the regulation being promulgated. It is the Agency judgment that such systems are specifically excluded from regulation under Section 17 of the Noise Control Act of 1972 by the definition of "carrier" cited in the Act, which excludes " . . . street, suburban, and interurban electric railways unless operated as a part of a general railroad system of transportation." In addition, such systems operate principally within one jurisdiction or in some cases throughout a small number of contiguous metropolitan jurisdictions under the purview of a single transit authority and, as such, do not appear to require uniform Federal regulation to facilitate interstate commerce. However, the exclusion of such systems does not also exclude the operations and equipment associated with commuter rail services provided by a number of interstate rail carriers.

Trains

Unlike the categories of railroad equipment and facilities just discussed, train noise is potentially subject to the noise regulations of more than one jurisdiction. Trains are constantly moving from one jurisdiction to another, and it is not feasible to have them stopped at policital boundaries and adapted to meet a different noise standard. Moreover, they constitute a major source of noise to people close to railroad rights-of-way. The various sources of train noise (other than warning devices) are therefore covered by the regulation to facilitate interstate commerce through uniform national treatment of their control.

CHARACTER OF RAILROAD NOISE SOURCES AND ABATEMENT TECHNOLOGY

Locomotives

Railroad locomotives are generally categorized as

- Steam
- Diesel-electric
- Electric
- Gas turbine.

The few remaining steam locomotives in the United States are preserved primarily as historical curiosities and are, therefore, not covered by the proposed regulations. In this subsection, noise associated with diesel-electric and electric/gas turbine locomotives are presented.

All measurements discussed in this section are A-weighted levels obtained by means of microphones places alongside a locomotive, and refer to a measurement distance of 100 feet, unless otherwise noted. Details of the measurements are given in Section 6.

Diesel-Electric Locomotives

Three types of engines are currently in use:

1. Two-stroke Rootes blown
2. Two-stroke turbocharged
3. Four-stroke turbocharged.

A turbocharged engine produces about 50 percent more power than does a Rootes-blown engine. The number of cylinders on a diesel engine may be 8, 12, 16, or 20, with each cylinder having a displacement of 640 cu in. Each cylinder produces 125 hp when Rootes blown and 187.5 to 225 hp when turbocharged. These engines are employed on the two basic types of locomotive:

1. The switcher, which is used primarily to shunt cars around the railroad yard and is powered by engines of 1500 hp or more.

2. The road locomotive, which is used primarily for long hauls, and is powered by engines of 1500 hp or more.

A diesel locomotive engine drives an electric alternator that produces electricity to run the electric traction motors attached to each axle of the locomotive. The rated power of the engine is the maximum electrical power delivered continuously by the alternator. The engine has eight possible throttle settings. As can be seen in Table 5-1, engine power and noise levels increase with throttle position. The data in this table are taken from a presentation given at an Associated of American Railroads (AAR) meeting in August 1973, by the Electro-Motive Division (EMD) of General Motors Corporation and were developed from a study of local cell information for a number of U.S. railroads. Of the approximately 27,000 locomotives in service on major railroads (see Appendix A), about 20,000 were built by EMD. The percent of horsepower and percent of time given for each throttle position are typical of all locomotives. The dBA levels vary, of course, from engine to engine. The example here is for a 2000 hp, EMD GP40-2 locomotive.

TABLE 5-1
EFFECT OF THROTTLE POSITION ON ENGINE POWER AND NOISE LEVELS

Throttle Position*	% of Rated hp for Diesel Engines	% of Time at Throttle Position		dBA at 100 Ft for 2000 hp Engine
		Road Loco	Switcher	
Idle	0.75†	41	77	69.5
1	5	3	7	72.0
2	12	3	8	74.0
3	23	3	4	77.0
4	35	3	2	80.0
5	51	3	1	84.5
6	66	3	–	86.0
7	86	3	–	87.5
8	100	30	1	89.0*

*Three cooling fans were operating during measurement for throttle position 8, only one fan for other measurements.

†Locomotive auxiliary hp only—no traction.

Locomotive at Rest

During the course of this study, sound level measurements were made on individual locomotives at different power settings during load-cell or self-load testing. The results of these tests are shown in Table 5-2.

For those locomotives listed in Table 5-2, the average overall noise level for the EMD locomotives at 100 ft is 90 dBA ±4 dBA, where the variance includes allowances for all possible measurement and locomotive differences; for example, different observers and different test sites. The GE measurement for its 3000-hp locomotive is 86 dBA ±3 dBA, again allowing for all possible measurement variations, which is slightly lower than those measured by EMD. The reason for this difference may be that on GE locomotives, the exhaust stacks rise about 6 in. above the hood, while on EMD locomotives the stacks are flush with the hood and radiate sound more efficiently.

In addition to exhaust and casing noise, the noise from cooling fans may be significant. Figure 5-1 shows that the noise from an EMD GP-40-2 3000-hp locomotive with its engine access doors open measured 9 dBA higher with three cooling fans running than with no fans running. Since it was necessary to open the engine access doors during the measurements, the recorded levels are somewhat higher than would be generated under normal operating conditions. However, there is little doubt that cooling fan operation can significantly contribute to overall levels. The fans on GE engines run continuously, thus contributing to total noise levels under all operating conditions. Fans on EMD locomotives are thermostatically controlled.

In summary, the major components of locomotive noise are, in order of significance, engine exhaust noise, casing-radiated noise, cooling fan noise, and wheel/rail noise. Table 5-3 shows average levels in dBA at 100 ft for each of these sources. Other sources, such as engine air intake, traction motor blowers, and the traction motors themsleves have noise levels too far below the other sources to be identified. Also, Rootes-blown engines have an unpleasant "bark", which does not show up in any generally used method of measurement.

Locomotive in Motion

Another method of characterizing locomotive noise is doing so as a locomotive passes by a fixed point during normal operation. Levels recorded in this manner contain all sources of locomotive noise discussed previously. Measurements of this nature are meaningful, since this is the noise that is emitted into the community. Unfortunately, the specific parameters that affect the level of noise produced are not easily controlled. These include horsepower, velocity, throttle setting, and number of locomotive units coupled together. However, by recording the sound levels of a large number of passby events, typical levels may be established.

Figure 5-2 and Table 5-4 display the results of approximately 105 passby events. As indicated, locomotive passbys range from 74 dBA to 98 dBA when measured at 100 feet.

Figure 5-3 shows, for the same events, the maximum sound level as a function of the velocity. There does not appear to be a definitive relationship between speed and maximum locomotive noise.

Figure 5-4 relates, again for the same events, the maximum sound levels as a function of velocity and number of locomotives. There does not appear to be a definitive relationship between the number of coupled locomotives and the noise emitted.

The measurement of locomotive passby events is explained in Section 7.

TABLE 5-2

STATIONARY NOISE EMISSION DATA FOR GENERAL MOTORS AND GENERAL ELECTRIC LOCOMOTIVES

Locomotive Identification	Horsepower	Loading Conditions	Aspiration	Throttle Setting		Reference
				0	8	
EMD-SW1500	1500	T	--	--	84.5**	3
EMD-F7A	1500	T	--	66*	86	1
EMD-SW1500	1500	T	--	69*	92*	1
EMD-SW1500	1500	T	--	--	93	3
EMD SD 9 SD 4328	1750	T	RB	68	89	11
EMD 25014 SD 9	1750	--	RB	70	--	10
EMD-GP/SD38	2000	T	--	--	91.5	3
EMD 5077 GP 38-2	2000	S	RB	65	91	7
EMD GP 38-2 535	2000	S		67	88.5	7
EMD GP 38-2 535	2000	T	--	66.5	88.5	7
EMD 4115 72635-1 GP 38-2	2000	S	TC	66*	91	8
EMD 4111 72735-12 GP 38-2	2000	S	RB	63*	90	8
EMD 4053 5806-4 GP 38-2	2000	S	RB	62*	88	8
EMD 4050 5806-1 GP 38-2	2000	S	RB	61*	89	8
EMD 4508 SD 24	2400	T	TC	68	86.5	9
SD 35 1921	2500	T	--	69	86	7
EMD 29355 SD 35	2500	T	TC	68	88	8
EMD 1952 29340 SDP 35	2500	S	TC	70	88	8
EMD FP/SD-40	3000	T	--	72	89.5	3

TABLE 5-2 (Cont'd)

STATIONARY NOISE EMISSION DATA FOR GENERAL MOTORS AND GENERAL ELECTRIC LOCOMOTIVES

Locomotive Identification	Horsepower	Loading Conditions	Aspiration	Throttle Setting 0	Throttle Setting 8	Reference
EMD GP 40 3049	3000	T	--	64.5	88	7
EMD GP 40 3018	3000	T	--	69.5	88.5	7
EMD GP 40 3182	3000	T	--	67	85.5	7
EMD GP 40 3195	3000	T	--	68.5	88	7
EMD GP 40 3156	3000	T	--	67	88	7
EMD 1559 32623 GP 40	3000	T	TC	69	92	8
EMD 1562 32960 GP 40	3000	T	TC	68	87	8
EMD-GP40-2	3000	T	--	70*	88*	7
EMD 3115 SD 45	3200	S	TC	68	90	8
EMD 3124 SD 45	3200	S	TC	70	90	8
EMD SD 45-T2 SP 9212	3600	S	TC	72	94	11
EMD SD 45	3600	T	--	--	90.5	3
GE U25	2500	T	--	--	86*	5
GE 38573 4300	3000	--	TC	72	--	10
GE 1472 38417 U30C	3000	S	TC	66*	89	8
GE 1581 37970 U30C	3000	S	TC	65*	87	8

TABLE 5-2 (Cont'd)

STATIONARY NOISE EMISSION DATA FOR GENERAL MOTORS AND GENERAL ELECTRIC LOCOMOTIVES

Locomotive Identification	Horsepower	Loading Conditions	Aspiration	Throttle Setting		Reference
				0	8	
GE 1473 38418 U30C	3000	S	TC	67*	87	8
GE U30	3000	T	--	--	86*	4
GE 3811 U33C	3300	S	TC	68	90	8
GE 8717 U36C 38879	3600	S	TC	72	91.5	9
GE U36B 1759	3600	S	--	68	91	
GE U36B 1825	3600	S	--	67	93	7
GE U36B 1780	3600	S	--	66	90.5	7
GE U36B 1855	3600	S	--	66	85.5	7
GE U36B 1832	3600	S	--	65	89.5	7
GE U36B 1815	3600	S	--	64.5	90	7
GE 1767 37430 U36B	3600	S	TC	66	87	3
GE 1796 37792 U36B	3600	S	TC	67	91	8
GE 1766 37429 U36B	3600	S	TC	67	93	8
GE 1771 37434 U36B	3600	S	TC	67	91	8
GE 1764 37427 U36B	3600	S	TC	67	94	8

TABLE 5-2 (Cont'd)

STATIONARY NOISE EMISSION DATA FOR GENERAL MOTORS AND GENERAL ELECTRIC LOCOMOTIVES

Locomotive Identification	Horsepower	Loading Conditions	Aspiration	Throttle Setting		Reference
				0	8	
GE 1526 38048 U36B	3600	T	TC	66	90	8
GE 1800 37796 U36B	3600	S	TC	68	92	8
GE U36B	3600	S	--	64.5	90	7
	Sample Size			47	51	

S - Self Load
T - Load Cell
TC - Turbo Charged
RB - Rootes Blown

*Data taken at 50 ft.; 6 dBA added

**Pre-1960 muffler

	Idle	Throttle 8
Range	61-73 dBA	84.5-94 dBA
Mean	67.3 dBA	89.3 dBA
Standard Deviation	2.45 dBA	3.36 dBA

REFERENCES TO TABLE 5-2

1. R. A. Ely, "Measurement and Evaluation of the Impact of Railroad Noise Upon Communities," BBN Report No. 2623, August 1973.
2. E. K. Bender and R. A. Ely, "Noise Measurements In and Around the Missouric Pacific Centennial Yard, Fort Worth, Texas," BBN Report No. 2648, October 1973.
3. Electromotive Division of General Motors, presentation to American Association of Railroads, August 8, 1973.
4. General Electric, presentation to American Association of Railroads, August 8, 1973.
5. J. W. Awing and D. B. Pies, "Assessment of Noise Environments Around Railroad Operations," Wyle Laboratories Report WCR-73-5, July 1973.
6. E. J. Rickley, Department of Transportation, Transportation Systems Center, unpublished data.
7. M. Alakel, C. Malme, M. Rudd, Bolt Beranek and Newman Inc., unpublished data.
8. EPA Region IV study of locomotive noise, unpublished data.
9. EPA Region VII study of locomotive noise, unpublished data.
10. EPA Region VIII study of locomotive noise, unpublished data.
11. EPA Region IX study of locomotive noise, unpublished data.

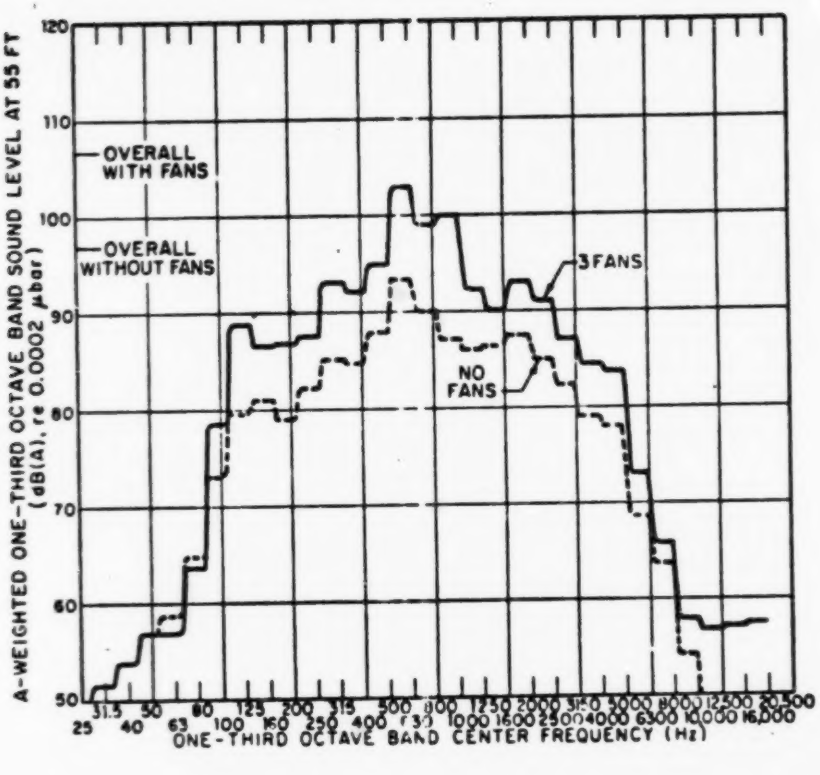

Figure 5-1. Effect of Fan Noise on the A-Weighted Spectrum of EMD GP40-2 Locomotive Noise at 55 ft (Engine Access Doors Open)

TABLE 5-3
SOURCE CONTRIBUTIONS TO LOCOMOTIVE NOISE LEVELS
(Based on Prediction Techniques of Ref. 4)

Source		dBA at 100 Ft (Throttle 8)
Exhaust		86--93
Casing		80–85.5
Cooling Fans		80–84
Wheel/Rail at 40 mph	Locomotive only	78
	Total train	81

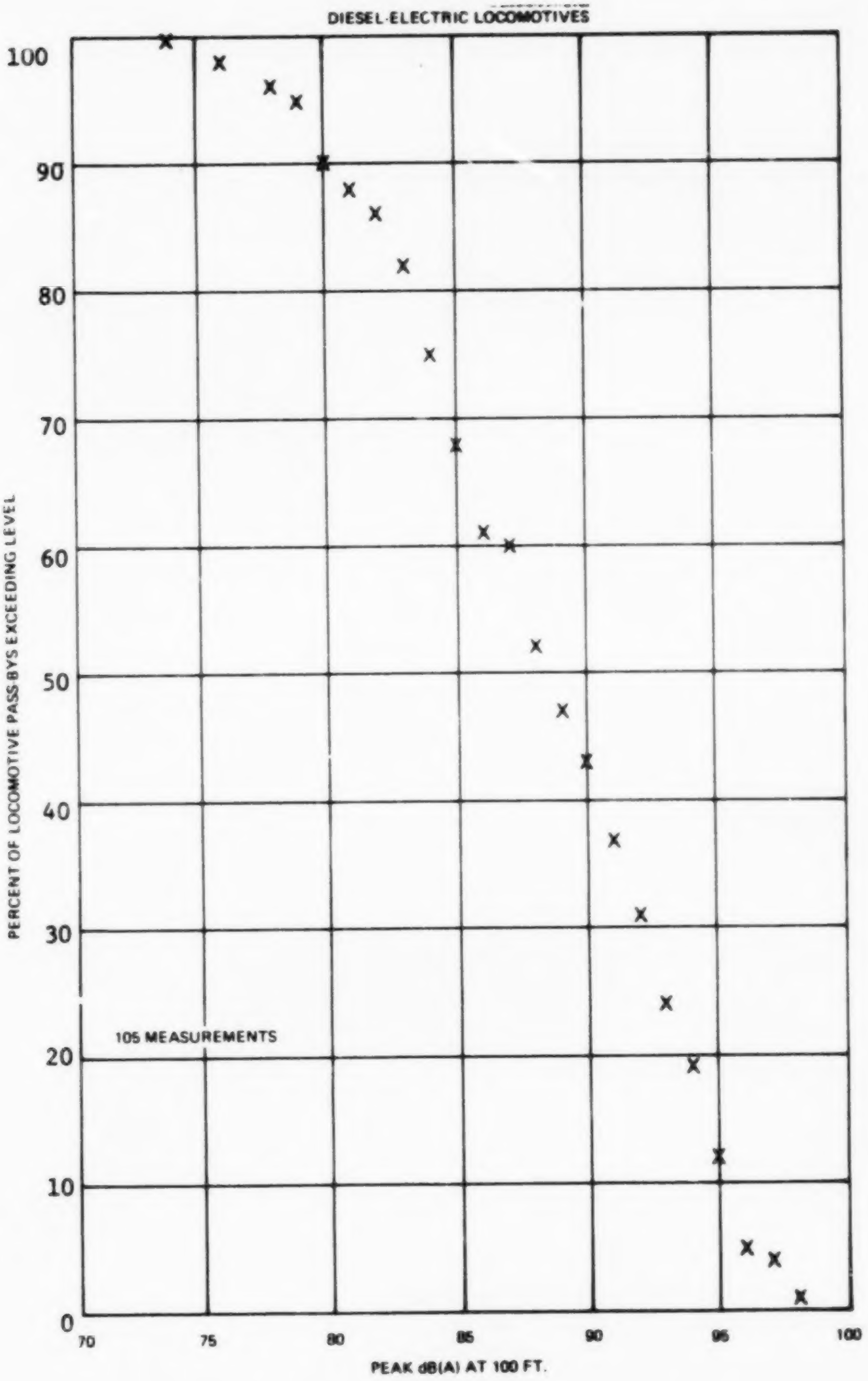

Figure 5-2. Diesel-Electric Locomotive Passbys

TABLE 5-4
LOCOMOTIVE PASSBY NOISE EMISSION LEVELS MEASURED AT 100 FEET

(see Figure 5-3)

dBA	Road Noise Studies				
	I	II	III	IV	TOTAL
74	1	1			2
75					
76				2	2
77					
78				1	1
79	1	1	2	1	5
80	2				2
81				2	2
82	2			2	4
83	4	1	1	2	8
84	3	1		3	7
85	3	1		4	8
86			1		1
87	1	2	3	2	8
88	2			3	5
89	1		2	1	4
90	2	3	2		7
91	4			2	6
92	2	1	4		7
93	3		2	1	6
94	4		3		7
95	3	1	2	1	7
96	1				1
97			2	1	3
98	1		1		2

I. Department of Transportation – Office of Noise Abatement
II. Department of Commerce – National Bureau of Standards
III. Wyle Laboratories
IV. Environmental Protection Agency – Office of Noise Abatement and Control

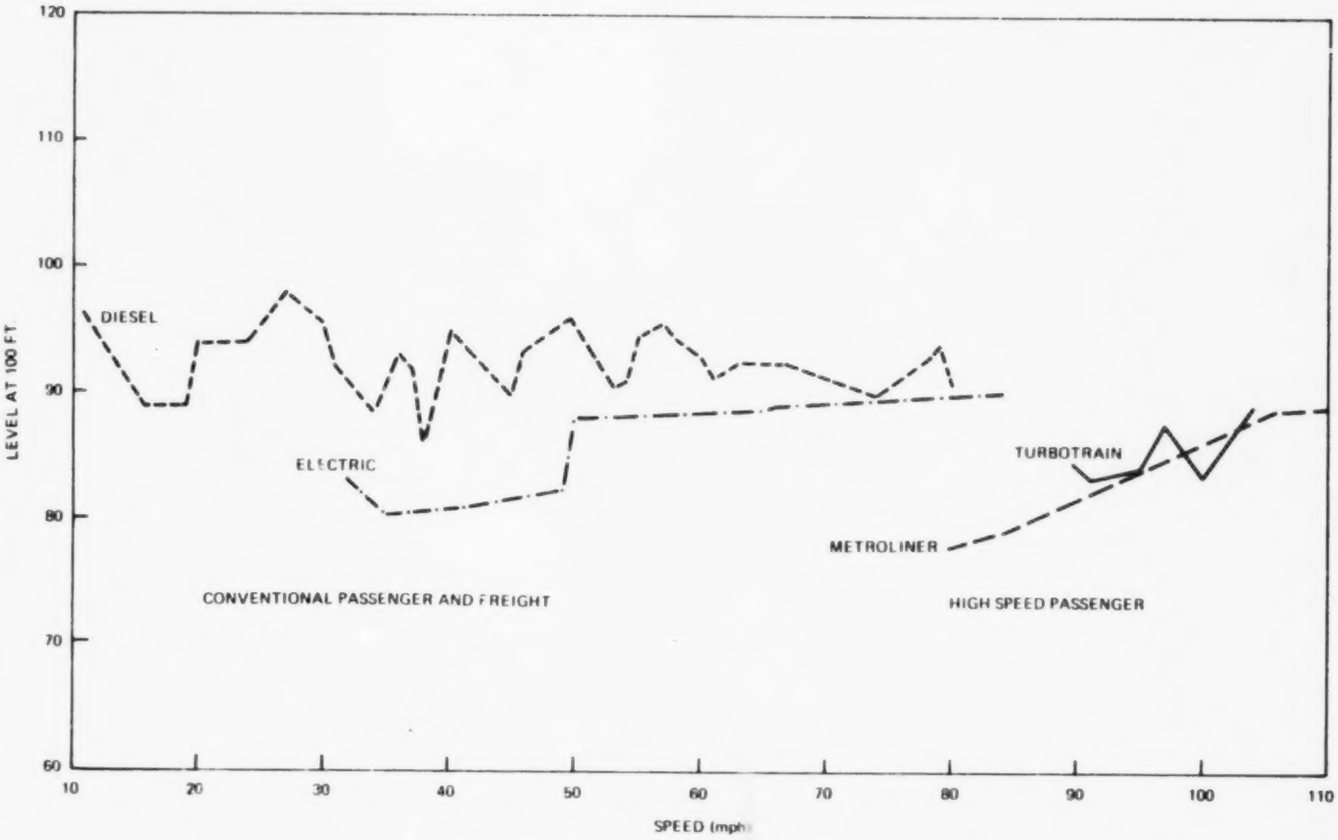

Figure 5-3. Peak Locomotive Noise Level vs. Speed

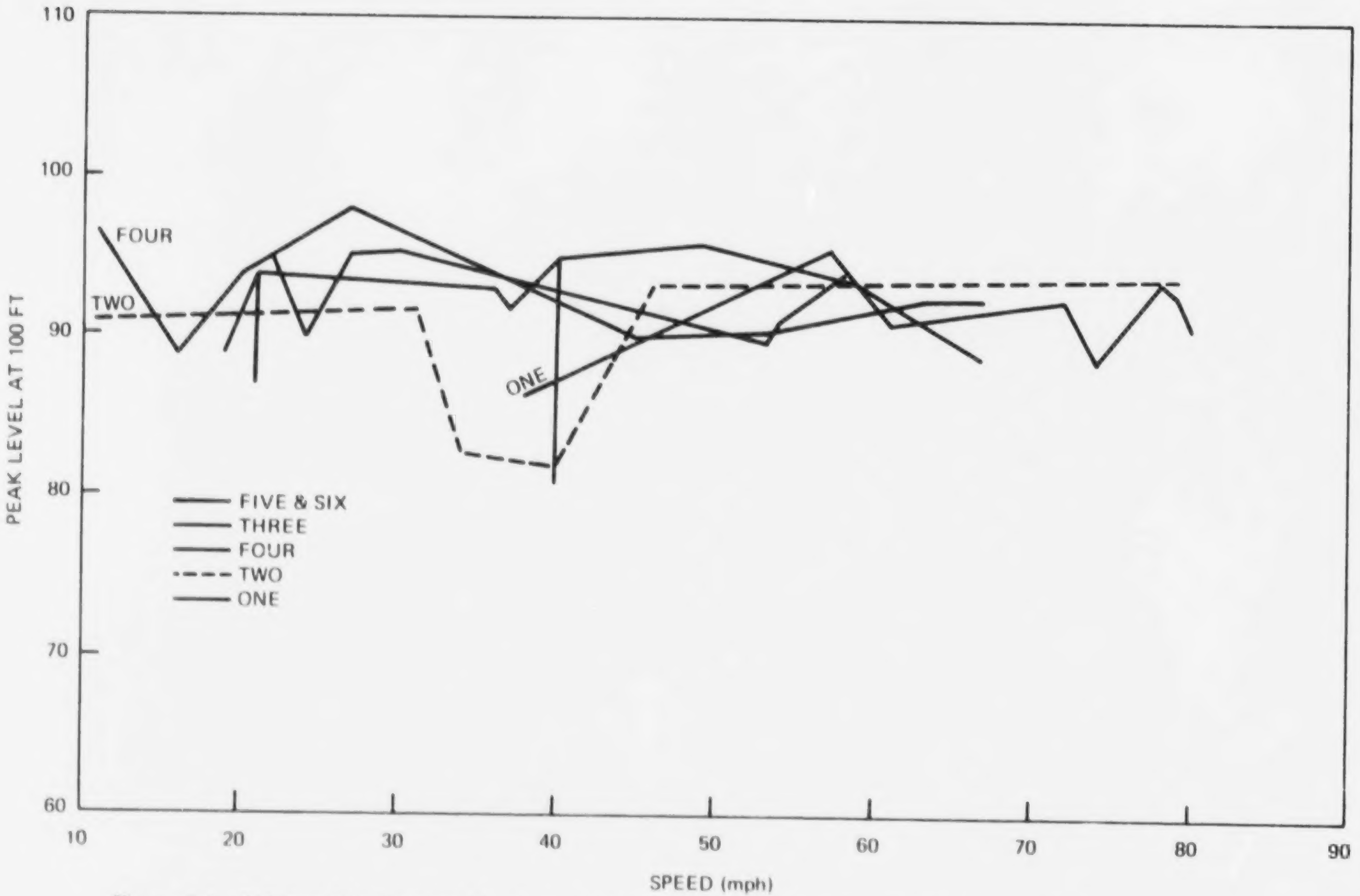

Figure 5-4. Relationship Between Maximum Noise Level and Number of Coupled Locomotives

Locomotive Noise Abatement

Locomotive noise abatement may be grouped into two broad categories:

1. Abatement by equipment modification
2. Abatement by operational procedures.

Abatement By Equipment Modifications

Mufflers. Since locomotives contribute most of the noise of railroad operations and since exhaust noise dominates locomotive noise, the first step in reducing locomotive sound levels is to require that locomotives be fitted with an effective muffler. This section contains muffler manufacturer estimates of various factors affecting the feasibility of supplying both new and in-service locomotives with mufflers. (Please refer to Appendices G, I, M, and N for discussions of muffler design, space availability, nonrailroad muffler applications, and AMTRAK experience with muffled locomotives.)

One such factor is the amount of back pressure a muffler creates. Back pressures on the engine may affect its performance and life to a small extent. The engine must pump against the back pressure, thereby reducing the power that can be distributed to propel the train. Normally, this degradation in performance is about 1.0 percent when back pressures are held within manufacturer limits. Back pressure may shorten engine life because when gases with increased temperature and density exhaust into a region of high pressure, they raise the temperature of exhaust valves and turbochargers. The following information on back pressure and its effects was determined by muffler manufacturers.

Engine Type	Back Pressure	Effect
Rootes Blown	47.5 in. H_2O measured at engine exhaust port	
Turbocharged	5 in. H_2O measured at exhaust stack	10° rise in turbocharger temperature 20-hp loss on 3000 hp engine 0.6% increase in fuel consumption

Mufflers have no appreciable effect on exhaust emissions; muffler-equipped locomotives give off insignificant incremental amounts of NO_X, CO, and smoke (EMD (1973)).

Three manufacturers with experience in fabricating mufflers for locomotives have indicated that their products will materially assist the railroads in complying with the proposed regulations: Donaldson of Minneapolis, Minn.; Harco Engineering of Portland, Ore.; and Universal Silencer of Libertyville, Ill. The following are these manufacturer's estimates of the attenuation that could be achieved with their mufflers alone, without any allowance installation, and the amount of back pressure they create.

Donaldson has had experience with the Chicago and Northwestern Railroad in equipping a locomotive with an off-highway truck type of muffler. The results were:

- Muffler Cost* – approximately $800 for two mufflers
- Back Pressure – further testing necessary

Harco Engineering has achieved the following results for a switcher locomotive. The muffler is fitted to a Harco spark arrester [20].

- Attenuation – approximately 5 dBA**
- Muffler Cost – $75

The results for road locomotives are:

- Rootes Blown

  Attenuation – approximately 10 dBA**
  Muffler Cost – $750

- Turbocharged:

  Attenuation – approximately 10 DBA**
  Muffler Cost – $1000
  Back Pressure – 13-20 in. H_2O (EMD claims that the back pressure is too high)

Universal Silencer has built mufflers for EMD locomotives (3 DRG and 40 AMTRAK). According to EMD (presentation at AAR meeting, 1973) these mufflers achieved:

- Attenuation – 9-10 dBA at full power
- Muffler Cost – approximately $1200
- Back Pressure – 3 in. H_2O

The estimated overall noise that would result from equipping various locomotives with mufflers that give 5 and 10 dBA attenuation in throttle 8 is indicated in Table 5-5.

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*Muffler cost figures are given in 1973 dollars.

**This measurement was performed by the manufacturer.

TABLE 5-5

LOCOMOTIVE NOISE LEVELS EXPECTED FROM EXHAUST MUFFLING, THROTTLE 8

	5 dBA Exhaust Muffling		10 dBA Exhaust Muffling	
Locomotive Type	Total Noise Level (dBA)	Total Attenuation (dBA)	Total Noise Level (dBA)	Total Attenuation (dBA)
EMD 1000-hp Rootes Blown Switcher	86.0	4.0	82.0	8.0
EMD 1500-hp Rootes Blown Switcher	88.0	4.0	84.0	8.0
EMD 2000-hp Rootes Blown Road Locomotive	89.0	4.0	85.0	8.0
EMD 3000-hp Turbocharged Road Locomotive	86.5	3.5	84.5	5.5
GE (or Alco) 3000-hp Turbocharged Road Locomotive	87.5	3.0	86.5	4.0
EMD 3600-hp Turbocharged Road Locomotive	87.5	3.5	85.5	5.5
GE (or Alco) 3600-hp Turbocharged Road Locomotive	88.5	3.0	87.5	4.0

*Because of problems integrating with spark arrester.

Muffler manufacturers have said that they could supply fully developed and tested muffler systems for all locomotives by the following dates within the 4-year period allotted for design, development, and installation:

HARCO

Switchers	1 January 1974
Road	1 January 1976

DONALDSON

All types	1 January 1976

UNIVERSAL SILENCER

Turbocharged Locos	1 January 1976
Rootes Blown	1 January 1977
Switchers	1 January 1978

EMD and GE have said that they could fit mufflers on new locomotives by the following dates.

EMD		
Turbocharged	Road	1 January 1976
Rootes Blown		1 January 1977
Switchers		1 January 1978*
GE		
Turbocharged		1 January 1976

EM and GE agree that mufflers can be incorporated in new locomotives. The cost of installing mufflers on locomotives must be compared with a total cost of $300,000 to $400,000 per locomotive (GE and EMD presentations to AAR meeting, 1973). The following methods would be used by each locomotive manufacturer in fitting mufflers on new engines.

- *New GE Road Locomotives.* Mufflers would be installed above the engine, and the hood roof would be raised 8 in. A locomotive would still clear the required 15-ft, 7-in. gauge. Cost * = $1500 per locomotive.

- *New EMD Road Locomotives.* Turbocharged – The muffler would be installed over the turbocharger. Mountings would have to be changed, as would the roof structure, brake cabling, and extended range dynamic brakes. Cost = $2500 per locomotive.

  Rootes Blown – The muffler would be integrated with the spark arrester. There would be changes to the dynamic brake contactors, roof structure, and coolant piping. Cost = $3000 per locomotive.

- *New EMD Switchers.* The muffler would be integrated with the spark arrester, but EMD is not quite sure how. Cost = $200–$500 (estimate based on Harco figures).

- *Retrofitting Older Locomotives.* Retrofitting mufflers on locomotives involves finding out how many of each type of locomotive are still in service and adopting muffler installation procedure to the peculiarities of each model.

Table 5-6 illustrates the distribution of switchers in service, categorized by manufacturer.

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*Cost estimates cited here for fitting new locomotives with mufflers are based on 1973 quotations as given by EMD and GE and are expressed here in 1973 dollars. For a complete discussion of new locomotive muffling costs please refer to Section 9.

TABLE 5-6
SWITCHER LOCOMOTIVES IN SERVICE

Manufacturer	Year Built	No. in Service
EMD	1940-59	3200
	1960-present	1100
ALCO	1940-61	950
GE	1940-58	116
Baldwin, Lima Hamilton	1946-56	415
Fairbanks Morse	1944-58	220
		TOTAL 6000

Few new switchers are being built, only about 120 per year, since switchers appear to run indefinitely. Furthermore, old road locomotives can be downgraded for switching use.

Most switching locomotives built before 1960 were equipped with mufflers, but after 1960, railroads generally fitted spark arresters instead.

In general, there does not seem to be any difficulty in fitting a muffler to the exhaust stack above the hood of a switcher. This has already been done in many cases with spark arresters, resulting in some loss in visibility for the driver. Harco has designed and tested a muffler that integrates with its spark arrester. The Harco muffler costs $75. However, this unit may have inadequate muffling for the regulation or too high a back pressure. Keeping this in mind, EPA estimates the cost of other spark arresters to be $200 to $500 plus 1 man-day of labor for installation.

The 8758 EMD Rootes-blown road locomotives built before 1 January 1972 have less space for mufflers than the new model GP/SD 38-2. Care must be given to the siting of mufflers, but installation is considered to be possible. The dynamic brake grids will have to be resited, and the roof structure will have to be modified. Railroads might have changed exhaust systems on rebuilding. Discussions with a representative from Penn Central have led to the following cost estimates for fitting each of these older models with a muffler. Please refer to Section 6 for a comprehensive discussion of retrofit costs.

Muffler = $1500
Labor = 25 man-days ($/man-day=$46.40)
Parts = $200–$500

Labor covers the resiting of dynamic-brake grids, plumbing and cabling, modifying the roof structure, and installing the muffler.

Mufflers that produce 5 to 10 dBA of exhaust muffling are currently feasible. It is important that a muffler be designed to give as good muffling at idle as at full power, since locomotives idle much of the time. Unless other noise sources on the locomotives are also treated, the net locomotive quieting will be only about 6 dBA due to contributions from these sources (see Table 5-4).

Mufflers could be developed and ready for production by January 1976. The manufacturers have sufficient capacity to produce the mufflers required.

Cooling Fan Modification. The next contributor to locomotive noise that may be treated is the cooling fan. Cooling fan noise is essentially aerodynamic noise resulting from the air movement created by the fan. Methods of treatment include increasing the diameter of the fan, adjusting clearances between blade and shroud, and varying the pitch of the blade. Although fan modifications are feasible, the application of fan retrofitting has not been developed for locomotives. Further, the impact of such a requirement could not be assessed with regard to cost and the effect on the total noise.

Engine Shileding. The vibration of the engine casing is a significant component of the total locomotive noise. On a limited basis, work has been done to reduce the noise from this source by adding acoustic panels to the engine, stiffening the engine casing, and using sound-absorbing materials. This technique has not been developed to the extent that it could be applied to locomotives at this time. Due to new data that demonstrates the dominant effects of casing-radiated noise at idle, the regulation as proposed has been amended to raise allowable long term idle emissions from 67 to 70 dBA. Please refer to Appendix F.

Noise Abatement By Operational Procedures

Parking Idling Locomotives Away from Residences. One of the most frequent complaints about railroad noise is that locomotives are left idling overnight. Railroads are reluctant to shut down locomotives, except during their monthly inspection, because:

- Shutting down and starting locomotives require a special crew.
- Engines do not contain any antifreeze in their cooling systems and would have to be heated in cold weather.
- Locomotive engines are likely to leak cooling fluid into the cylinders, which could damage an engine on starting if precautions were not taken to drain it.

Railroads are sometimes rather careless about where idling locomotives are left. Frequently they are parked on the edge of a rail yard close to residences. With a little effort, locomotives could be parked near the center of a rail yard, where they would be less troublesome to neighboring homes.

Speed Reduction. The power needed to pull a train increases almost directly with speed, but the noise of a given locomotive increases rapidly with speed. Thus, one could achieve some reduction by lowering the speed limit for trains passing through residential areas. For example, the throttle settings of the locomotives of passing trains would generally be lower, and, thus, the locomotive noise would be reduced. Further, other noise sources, such as wheel/rail noise, would also be reduced.

This noise reduction method may not be generally practical, except perhaps in special urban areas, since the net effect would be to slow the movement of train traffic. The cost to the railroads of lower speeds has not been calculated.

Ban on Night Operations. Many freight trains, particularly in the eastern United States, operate at night. Their noise is most disturbing at this time, since the background noise is lowest and people can be awakened from sleep. Thus, a significant impact on the annoyance resulting from the train noise can be made by banning night operations. However, such a ban on night operations would frequently be impractical, since trains are scheduled for markets that open in the morning and the trains are loaded during the previous day. The resulting burden on the flow of interstate commerce could be extensive.

Use of More or Larger Locomotives for a Given Train. One paradox emerged from the model of locomotive noise presented earlier. A large locomotive in a low throttle position develops less noise than a small locomotive in a high throttle position, even when the two develop the same horsepower. For example, a 3600-hp locomotive in throttle 4 generates 15 dBA less noise than a 2000-hp locomotive in throttle 8. Thus, a considerable noise reduction is achieved by using a 3600-hp engine to haul a train requiring only 2000-hp. Similarly, a 9-dBA reduction could be obtained by using four 3600-hp locomotives with lower throttle settings to pull a train that normally requires two 3600-hp locomotives, but which operate at high throttle settings.

This noise reduction technique is considered to be impractical in general, since the extra hauling power required is large. However, this method could be used in some situations, such as switching operations. Locomotive engineers could use low throttle positions rather than gunning the engine in throttle 8.

Electric/Gas Turbine Locomotives

There are other means of train propulsion, apart from diesel-electric, currently in use on American railroads. All-electric and gas turbine locomotives are becoming more popular, particularly in the Northeast corridor. Rickley, Quinn, and Sussan have measured the wayside noise levels of the Metroliner, Turbotrain, and electric passenger and freight trains. The levels at 100 ft are given in Table 5-7. In general, levels do not exceed 88 dBA. For those trains, namely two Metroliner trains and one standard passenger train, exceeding 88 dBA, it is felt that the cause was the wheel/rail interaction phenomena as opposed to locomotive engine-generated noise, *per se,* since these vehicles travelled at rates of speed at which rail noise is likely to predominate. (See discussion which follows.)

Thus, in passby situations, non-diesel-electric locomotive noise is well below that of diesel-electric locomotives, and the former are likely to comply with any regulation written for the latter. However, in the case of gas turbine locomotives, the Agency could not obtain data on stationary noise levels and, as such, has exempted them from compliance with the stationary standards. Stationary standards for gas turbine locomotives may be promulgated in the future.

Wheel/Rail Noise

Rail car noise includes all sources of train noise other than that produced by the locomotive. These sources are

- wheel/rail interaction
- structural vibration and rattle
- refrigerator car cooling system noise.

TABLE 5-7

NOISE LEVELS FROM ELECTRIC AND GAS-TURBINE TRAINS

Train	No. of Cars	Direction	Speed (mph)	SPL (dBA 100 ft)
Metroliner	4	South	106	89
	4	South	110	89
	4	North	106	84
	6	North	110	84
	4	North	80	78
	6	North	84	80
Electric Pass	6	South	84	90 (wheel/rail)
Electric Freight (2 Locos)	3	South	49	88
Turbotrain	5	East	97	85
	5	West	91	85
	3	East	89	84
	3	West	104	88

Of these sources, the interaction of the wheel and rail is the major component. As discussed in Reference 43, this source is generated by four mechanisms:

- Roar
- Impact
- Flange rubbing
- Squeal.

Roar describes the noise that predominates on welded tangent track. It is believed that roar is due to roughness on the wheels and rails.

Impact noise refers to the noise produced by wheel and rail discontinuities such as wheel flats, rail joints, frogs and signal junctions. This noise is characterized by a clickety-clack sound and may cause significant increase in wayside noise.

Flange rubbing describes the sound made when the flange contacts the rail and squeal does not occur. This noise is characterized by a low-frequency grinding sound. It could be caused by a stick-slip phenomenon or by roughness on the flange and rail head.

Squeal is a high pitched noise produced when a train negotiates a tight curve. Three possible ways in which squeal can occur are:

1. Differential slip between inner and outer wheels on a solid axle.

2. Rubbing of the wheel flanges against the rails.
3. Crabbing, or lateral motion of the wheel across the top of the rail.

Structural vibration and rattle emanate from the car bodies and couplings. Noise from these sources may be distinguishable in a slowly moving train. Normally, however, this noise combines with the other sources of car noise and is not readily distinguishable.

Refrigerator cars are railroad cars used to transport perishable freight requiring refrigeration. It is necessary for the cooling equipment to operate continuously when the car is loaded, and also when the car is empty but a load is anticipated. This cooling equipment usually contains a diesel engine, sometimes with muffler (of undetermined adequacy), to drive a compressor. These engines are similar in size and performance to engines used in other applications in a muffled configuration.

It is believed that the muffler industry could supply the additional muffler requirement for rail refrigerator cars. However, application consideration would also have to include space availability and installation and replacement costs. The maximum noise level from this source is approximately 75 dBA at 50 ft [40]. When a train is moving, the noise levels emitted from a refrigerator car cannot be distinguished from overall train noise; however, if the train stops or if the cars are held over, the continuous operation of the compressor engine may be a source of undesirable noise.

Refrigerator cars parked with their cooling systems running, as they often are in marshalling and humping hards, may cause noise problems, but only in places where refrigerator cars are parked near noise-sensitive areas. At this time, such localized problems can best be controlled as a part of railroad yard noise control, through measures such as parking refrigerator cars away from noise-sensitive areas or installing noise barriers, rather than by requiring modifications to the entire refrigerator car fleet. For an expanded discussion of reefer car noise please refer to Appendix O.

Typical measured levels of rail car noise are illustrated in Figures 5-5, 5-6, and 5-7. Figure 5-8 indicates that the A-weighted wheel/rail noise level varies as 30 log V, where V is the train velocity. This relationship primarily describes the roar component of the noise. The higher levels present are most probably indicative of impact, flange rubbing and squeal noise.

Wheel/Rail Noise Abatement

A number of techniques have been suggested to reduce noise from railroad cars operating on open track. In most cases, testing has been limited and, thus, the results regarding effectiveness are inconclusive.

Grinding of train wheels and rail would reduce roar noise by reducing the amplitude of the excitation. Bender and Heckl [44] report differences of approximately 6 dBA between noise levels for ground and unground rails on the Munich Subway. The important parameter to control during grinding is irregularities having wavelengths on the order of 0.5 inch to 1.0 foot, rather than the micro-surface finish. Such wheel irregularities (wheel flats) can be controlled by spinning the wheel during grinding. For rail, it is more difficult because running a vehicle with a grinding wheel attached slowly over the rails causes the grinder to move vertically in response to the vertical motion of the vehicle wheels.

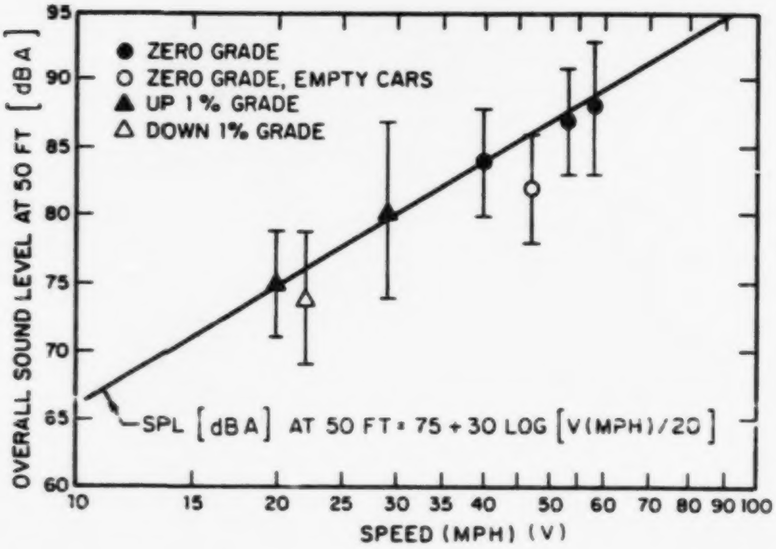

Figure 5-5. Wheel/Rail Noise Measured on Level Ground and on a 1% Grade

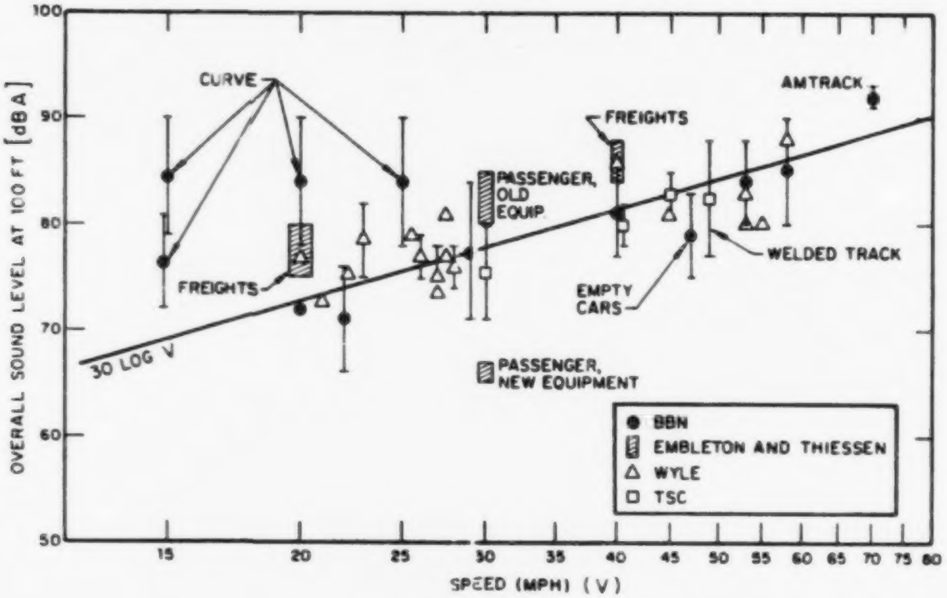

Figure 5-6. Measured Wheel/Rail Noise

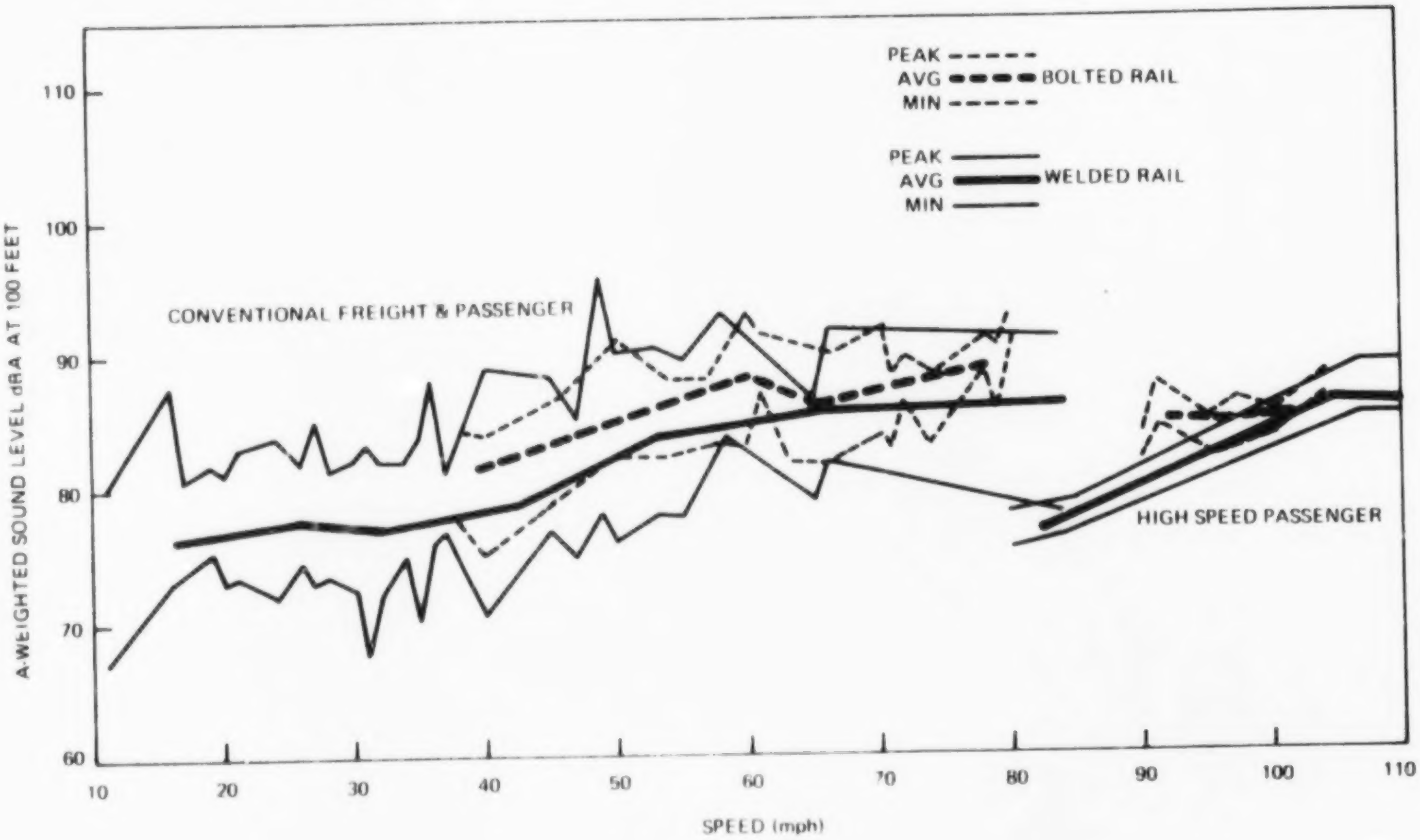

Figure 5-7 Average, and Minimum Rail-Wheel Sound Level vs. Speed for Typical Railroad Cars on Welded and Bolted Rail

The use of resilient wheels has undergone considerable development since they were invented in 1889. There are now four different designs available:

1. Penn Cushion wheels, available in the U.S. from Penn Machine Co., Johnstown, Pa.
2. Acousta Flex wheels, marketed by the Standard Steel Division of Baldwin-Lima-Hamilton Corporation, Burnham, Pa.
3. SAB resilient wheels, marketed in the U.S. by American SAB Company, Inc., Chicago, Illinois.
4. P.C.C. wheels, made by Penn Machine Co., Johnstown, Pa.

The Penn Cushion and Acousta Flex wheels are similar in principle. Both utilize an elastomeric ring between the rim and the hub of the wheel. The SAB and PCC wheels also are similar to each other in principle. In these wheels, the rim is part of a steel disc, and the hub assembly consists of one or more parallel steel discs. The rim disc is connected to the hub assembly via rubber elements that deform as the wheel is loaded radially. The experimentation and data for resilient wheels on rapid transit cars indicate that such wheels would be of negligible benefit for reducing railroad freight car noise. Freight cars operate principally on tangent track, where resilient wheels are least effective.

Another technique explored is wheel damping. B. F. Goodrich Company constructed a wheel with a layer of viscoelastic damping material bonded to the inside of the wheel rim and covered with a bonded steel constraining layer. This treatment is said to have eliminated screech, reduced far field noise obtained on tangent track by up to 2 dBA at high speeds, and attenuated rail vibration. Some limited experiments by B. F. Goodrich showed that use of an unconstrained viscoelastic layer resulted in no significant noise reduction. However, the Toronto Transit Commission found a 12 to 15 dBA squeal noise reduction when applying unconstrained damping layers. Use of a four-layer damping configuration on a BART prototype car had no significant effect on interior and wayside noise on tangent track, but eliminated some screeching on curved track. Reductions of 20 dBA in screeching noise and 4 dBA for nonscreeching noise were realized for curved track.

Rail welding is a method that can be used to reduce the noise caused by the discontinuities at rail joints. On the average, it can be expected to reduce wayside noise by as much as 3.5 dBA. However, maximum levels are as high on welded rail as on bolted rail (see Figure 5-8). Other advantages of welded rail are the potential for less maintenance and a decrease in average rolling resistance. Both are due to the absence of rail joints.

Rail damping is a technique that has undergone only limited testing. A damping compound is applied to the nonrunning surfaces of the rails, which should shorten the length of rail that vibrates when a wheel passes over it. At this time, experimentation is so limited that no conclusions can be reached as to the effectiveness of this technique.

In summary, although there are some new techniques and systems that show a degree of promise, the only available methods today for reducing moving rail car noise emissions is through the maintenance practices of car wheel and rail grinding, in addition to the use of welded rail. For a discussion of the applicability of track and rail safety standards to noise, please refer to Appendix P.

Retarder Noise

Within rail car classification yards, several thousands of cars are moved in each 24-hr period, as trains are assembled/disassembled. Two general methods are used for car movement:

1. Small switcher locomotives are used to maneuver (one or more cars) and to create rail car vehicle velocity prior to release for self-movement to pre-selected tracks.
2. Heavy duty pusher locomotives push rail cars up an incline and over a hump, where the cars are released to travel on their own to predetermined yard locations.

As a result of the technique used in hump yards, a single rail car or several rail cars coupled together may be traveling at 10 to 15 mph and accelerating while moving down the hump.

To manage the rail car(s), retarders are used to reduce car(s) speed or to stop them. In the process of slowing or stopping the car(s) intense noise, characterized as a squeal, is often generated. Figure 5-8 shows the amplitude distribution of noise associated with railcar movement through retarders. Noise levels as high as 120 dBA at 50 feet have been observed.

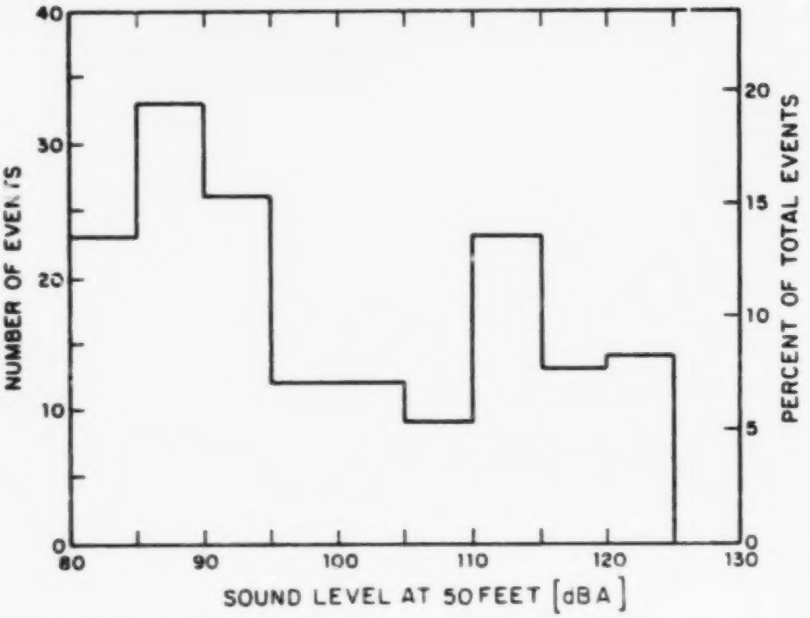

Figure 5-8. Retarder Squeal Amplitude Distribution

Although studies [36, 24] have been conducted to determine the mechanism of wheel/retarder noise generation, a thorough understanding of the phenomenon is not yet at hand. It is thought that the intense wheel squeal is the result of excitation of the rail car wheel at its resonant frequencies. Apparently, the noise levels emitted by the car wheels are influenced by car type, car weight and loading, type of wheels, structure and composition of the retarder, and the decelerating force that the retarder applies to moving cars.

According to the Federal Railroad Administration, there are approximately 130 hump yards in this country. A listing of the current in-use hump yards by location, railroad, and number of classification tracks is shown in Appendix C.

Retarder Noise Abatement

Though the mechanisms of wheel/retarder noise are not fully understood, several methods to control the noise are thought feasible. One method, namely, the use of barriers, would control the noise once it is generated. In other words, it would minimize the noise propagation efficiency, while four methods would control noise at the source; i.e., minimize noise generation efficiency.

1. Retarder lubrication
2. Use of ductile iron wheel shoes
3. Use of releasable inert retarders
4. Retarder control by computers.

While the five methods cited are thought to be possible alternatives for retarder noise control, much further study is required to assess the benefits and costs associated with each method. To date, known benefit and cost information associated with the aforementioned methods are summarized as follows.

Benefits

The only completed study that models the impact on people of retarder noise reduction was of the Cicero Yard outside of Chicago. (See Appendix D.) The results of that study showed that the reduction of retarder noise levels by 20 dBA allowed about 200 more people to be exposed to less than an L_{dn} of 65 dBA. The maximum reduction that would be experienced by any of the 200 people would be a 2 dBA change in L_{dn}. If retarders were completely silenced, the noise reduction would benefit only 200 more people (total of 400) as per the preceding criteria, according to the study.

Although it is not altogether accurate to project a study of a single yard to a national impact, if the assumption was made that Cicero Yard is typical of all rail yards, approximately 26,000 more people would be exposed to less than an L_{dn} of 65 dBA.

By reducing locomotive exhaust noise by 10 dBA in the Cicero Yard, approximately twice the benefit was realized (400 people less than 65 L_{dn}) than with the 20-dBA reduction in retarder noise, according to the study.

Costs*

- Barriers (material costs of initial installation only)

  1. $70 to $100 per linear foot.
  2. $75,000 to $150,000 per yard.
  3. $9.6 to $19.1 million for railroad industry.
  4. Maintenance/replacement costs unknown.
  5. Space and safety hazards unknown.
  6. Down time and track modification costs are unknown.

- Source Control

  1. Lubrication Systems (excludes maintenance/operation costs)

     a. Specific costs unknown, estimated by industry to be $375,000 to $750,000 per retarder system (master plus 4 to 8 group retarders) or 5 to 10 percent of total capital investment.

     b. Estimated initial cost of new equipment on basis--$150 million (assuming 200 retarder systems)

     c. Maintenance and operational down time and mofification costs to track system are unknown.

  2. Ductile Iron Shoe

     a. Initial cost ($37 per foot) is twice that of regular retarder shoes.

     b. Ductile shoes wear 10 times faster than regular retarder shoes.

     c. Estimated additional cost for using ductile iron shoes to replace present shoes is $150,000 per retarder system.

     d. Estimate of national cost impact to industry is $150 million (assuming 200 retarder systems).

     e. Yard down time is not included in this cost estimate.

  3. Releasable Inert Retarders

     a. Conversion of nonreleasable inert retarders to releasables cost $7,500 per retarder, not including labor, down time, or operation costs.

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*The cost of shutting down a yard or part of a yard during installation or maintenance of these systems could double or triple the estimated costs.

    b. The number of nonreleasable inert retarders in use is unknown. Gross estimate is 20,000.

    c. Estimate of national cost to convert is $150 million.

4. Computer Control of Retarders

    a. Computer control of retarders seems practicable only at the newer yards, where computer control systems were installed when the yard was built.

    b. There are approximately 40 computer controlled yards.

    c. The cost, during new construction of a yard, for computer control of a retarder system is $2.25 million.

    d. Cost of feasibility of retrofitting a yard with compuer control is unknown.

    e. If hardware installation costs were assumed to triple the new installation cost, the national cost impact for retrofit of existing yards for computer control would be $800 million, assuming 120 retarder systems.

Car-Car Impact Noise

The time histories of car-car impact noise illustrated in Figure 5-9 show some features of the physical phenomena that accompany car-car impact. The initial impact of the car couplers causes a crack, as illustrated by the sharp rise in sound level in both parts of the figure. The high-frequency portion of the mechanical energy fed into couplers often excites an entire car body. The second time-trace in the figure shows how, as the resulting vibrational energy decays exponentially, the radiated noise falls off proportionally. The time-trace for a tank car hitting two loaded flat bed cars shows the noise sometimes generated by secondary impacts as cars pull away from each other and coupler slack is subsequently taken up. The time-trace for the noise measured eight cars away from a point of impact shows how the energy from an impact can propagate along a chain of cars.

Warning Devices

This source of noise includes bells, horns, and whistles, which are sounded to warn pedestrians and motorists that a train is approaching a grade crossing. The noise level at 50 ft due to either a horn or a whistle is 105 dBA ±10 dBA. Of prime consideration in addressing these sources of noise is the measure of safety that they provide.

Methods of noise abatement for warning devices have not been fully evaluated. Some localities have required that the devices not be sounded, while others have required the opposite.

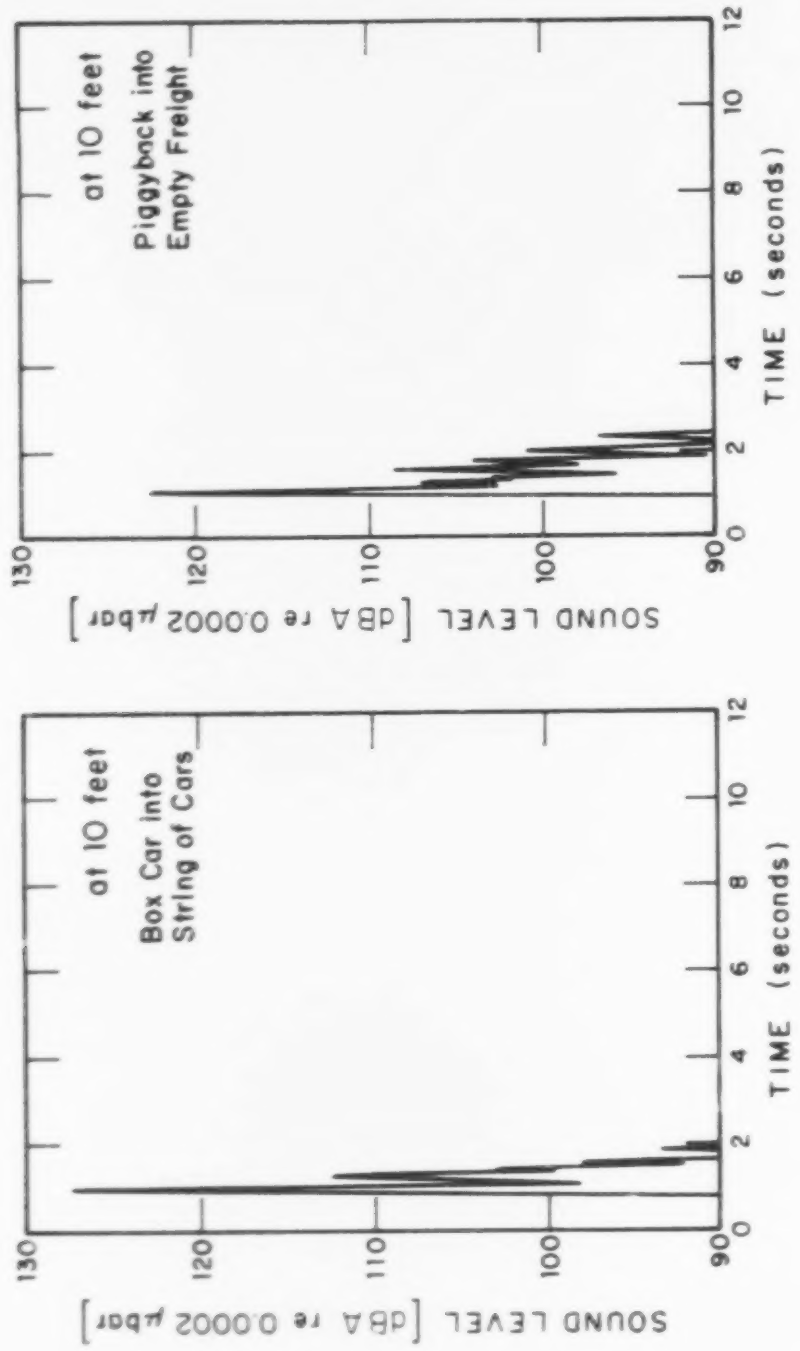

Figure 5-9. Car-Car Impact Noise Time Histories (Sheet 1 of 2)

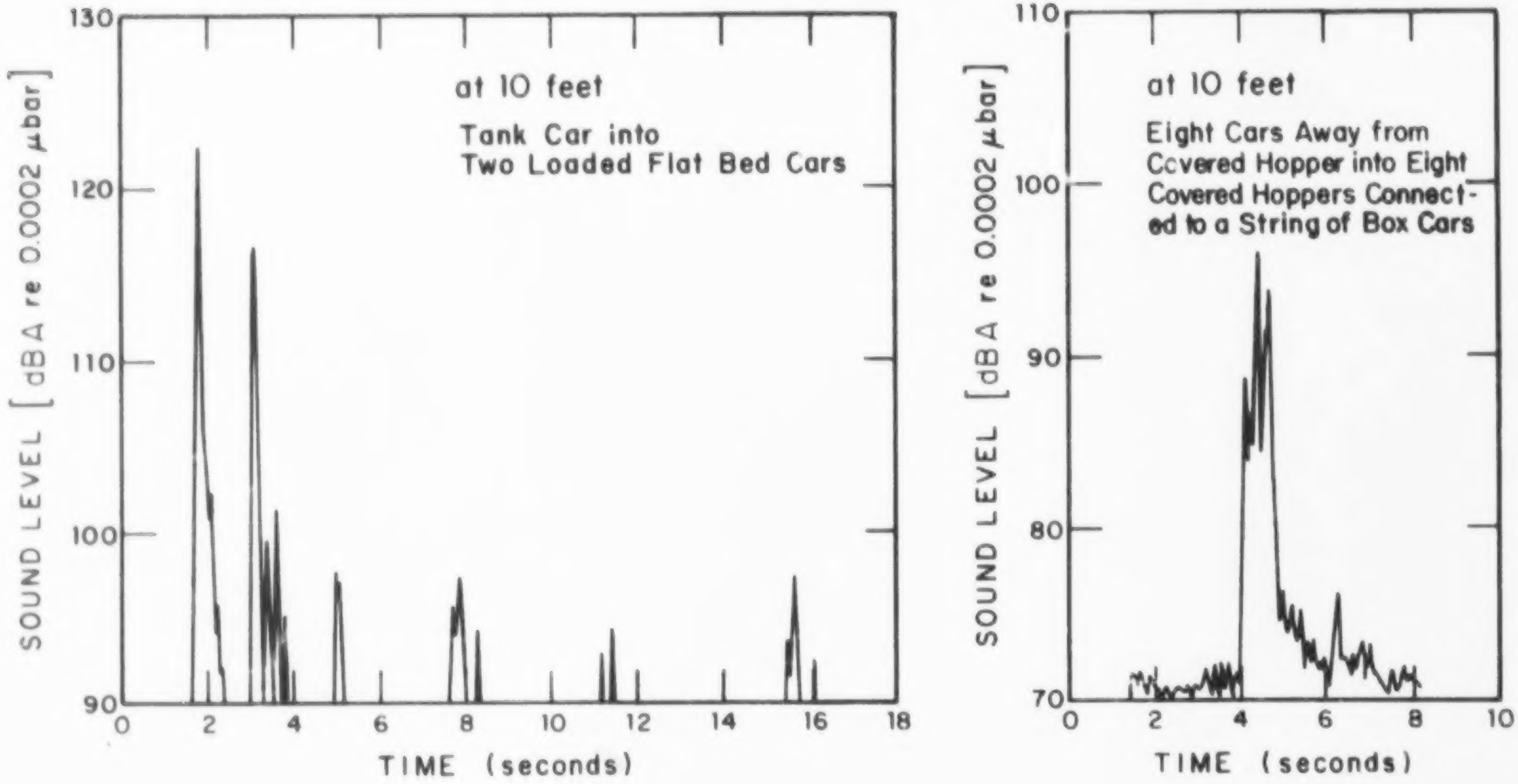

Figure 5-9. Car-Car Impact Noise Time Histories (Sheet 2 of 2)

Various alternatives for controlling their noise include requiring reduced levels, specifying directionality, or limiting the times and areas in which the devices should be sounded.

Public Address Systems

Although the frequency of occurrence of noise from loudspeakers in railroad yards is sporadic and unpredictable, the level of the noise from speakers is comparable to the level of noise from other sources in the yards. Where abatement is desired or necessary, more speakers could be strategically located so that less volume is necessary, or railroad yards could follow the recent trend to two-way radio communication.

Maintenance and Repair Shops

The noise from shops comes mainly from running the engines of stationary locomotives. Other noises from maintenance and repair shops are overshadowed by the noise from retarders, car impacts, and locomotives moving about the yard. If controls are applied to noise from locomotives, car impacts, and retarders, that part of shop noise not due to locomotive engines may then emerge as a significant part of the remaining noise.

Refrigerator Cars

These cars are railroad cars used to transport freight that requires refrigeration. It is necessary for the cooling equipment to operate continuously when the car is loaded and when the car is empty but a load is anticipated. This cooling equipment usually contains a diesel engine, sometimes with muffler (of undetermined adequacy), to drive a compressor. These engines are similar in size and performance to engines used in other applications in a muffled configuration. It is believed that the muffler industry could supply the additional muffler requirement for rail refrigerator cars. However, application consideration would also have to include space availability and installation and replacement costs. (see additional discussion under Wheel/Rail Noise in this section, as well as Appendix O.)

Auxiliary Diesel Engines

Passenger locomotives and cars are frequently equipped with (1) diesel engines to drive an alternator supplying electric power to the train, and (2) steam generators (on the locomotive) to supply heat for the train. AMTRAK is purchasing new locomotives with auxiliary diesel engines on board; some of their club cars already have them.

Data on noise levels from auxiliary engines were provided by the Illinois Railroad Association (IRA) in its submission to Docket ONAC 7201002. The IRA cited noise levels of two auxiliary engines as measured by the Chicago and Northwestern Railway. These engines were Cummins V-block diesels running at 1800 rpm so as to generate 60-Hz electricity. Noise measurements were taken with no load on the engines; they would have been higher if a load had been applied. The measured levels were 58 and 55 dBA at 100 ft from the locomotive.

Section 6

GENERAL PROCEDURE TO MEASURE RAILROAD NOISE

INTRODUCTION

The EPA did not propose or publish a detailed measurement methodology as part of its original rule making establishing railroad noise emission levels. The Agency did reference it in the Notice of Proposed Rule Making (NPRM) and described it in detail in the Background Document to the proposed railroad noise regulations. The proposed regulation did not include a detailed measurement methodology since it was contemplated that it would be included as part of the compliance regulation to be issued by the Department of Transportation (DOT).

Section 17 of the Noise Control Act of 1972 places the responsibility for promulgation of compliance regulations with the Secretary of Transportation. The EPA develops and promulgates standards that provide the basis from which DOT develops the requisite compliance regulations. Such EPA standards must be sufficiently detailed as to the requisite definition that there is no question as to the standard promulgated. Proper definition of such standards is particularly critical with respect to railroad noise because there is no generally accepted measurement scheme in use throughout the affected industry, unlike the situation in other industries subject to Federal noise regulation, such as the Motor Carrier industry.

A measurement methodology, dealing with the enforcement aspects of railroad noise measurement, will still be developed by the Department of Transportation. The Agency, however, as a result of its own further analysis and after consideration of the questions and suggestions received during the public review process, has decided to incorporate additional measurement criteria into the standards as an added subpart of the final regulation being promulgated herein. Such measurement criteria contain specifications for ambient noise, wind noise, test site conditions, test equipment orientation, and other parameters necessary for the consistent and accurate measurement of the sound levels specified in the regulation.

The criteria were derived from the EPA methodology which was published in the Background Document to the proposed regulation and commented on as a result of the public review process. That methodology has since undergone thorough review by concerned Agencies of the Federal government, including the Department of Commerce/National Bureau of Standards, and the Department of Transportation/Federal Railroad Administration, and been revised by the EPA in response thereto.

If issue is taken with the data supporting the railroad standards proposed by EPA, such data submitted to the Agency in support of the respondent's position should be based on measurement methods or procedures similar to those of the Agency. The equivalency of correlation between different measurement practices must be clearly explained, to permit adequate comparisons with the data and levels in regulation.

It is recommended that technically competent personnel select the equipment to be used for the test measurements. Proper test instrumentation and experienced personnel are essential to obtain valid measurements. Operating manuals or other literature furnished by the instrument manufacturer should be referred to, for both recommended operation of the instruments and precautions to be observed. Following are the measurement criteria as they appear in the regulation.

SUBPART C – MEASUREMENT CRITERIA

201.20 Applicability and Purpose

The following criteria are applicable to and contain the necessary parameters and procedures for the measurement of the noise emission levels prescribed in the standards of Subpart B of this regulation. These criteria are specified in order to further clarify and define such standards.

201.21 Quantities Measured

The quantities to be measured, under the test conditions described below, are the A-weighted sound levels for fast meter response as defined in the American National Standard S1.4-1971.

201.22 Measurement Instrumentation

(a) A sound level meter that meets, as a minimum, all the requirements of American National Standard S1.4-1971 for a Type II instrument shall be used with the "fast" meter response characteristic.

(b) In conducting the sound level measurements, the general requirements and procedures of American National Standard S1.13-1971 shall be followed. This publication is available from the American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.

(c) A microphone wind-screen recommended by the manufacturer of the sound level meter or microphone of an alternate sound level measurement system shall be used.

201.23 Acoustical Environment, Weather Conditions and Background Noise

(a) The standard test site shall be such that the locomotive or train radiates sound into a free field over the ground plane. This condition may be considered fulfilled if the test site consists of an open space free of large, sound reflecting objects, such as barriers, hills, sign-boards, parked vehicles, locomotives or rail cars on adjacent tracks, bridges or buildings within the boundaries described by Figure 6-1, as well as conforms to the other requirements of Section 201.23.

(b) Within the complete test site, the top of at least one rail upon which the locomotive or train is located shall be visible (line of sight) from a position 4 feet above the ground at the microphone location, except as provided in Section 201.23(c).

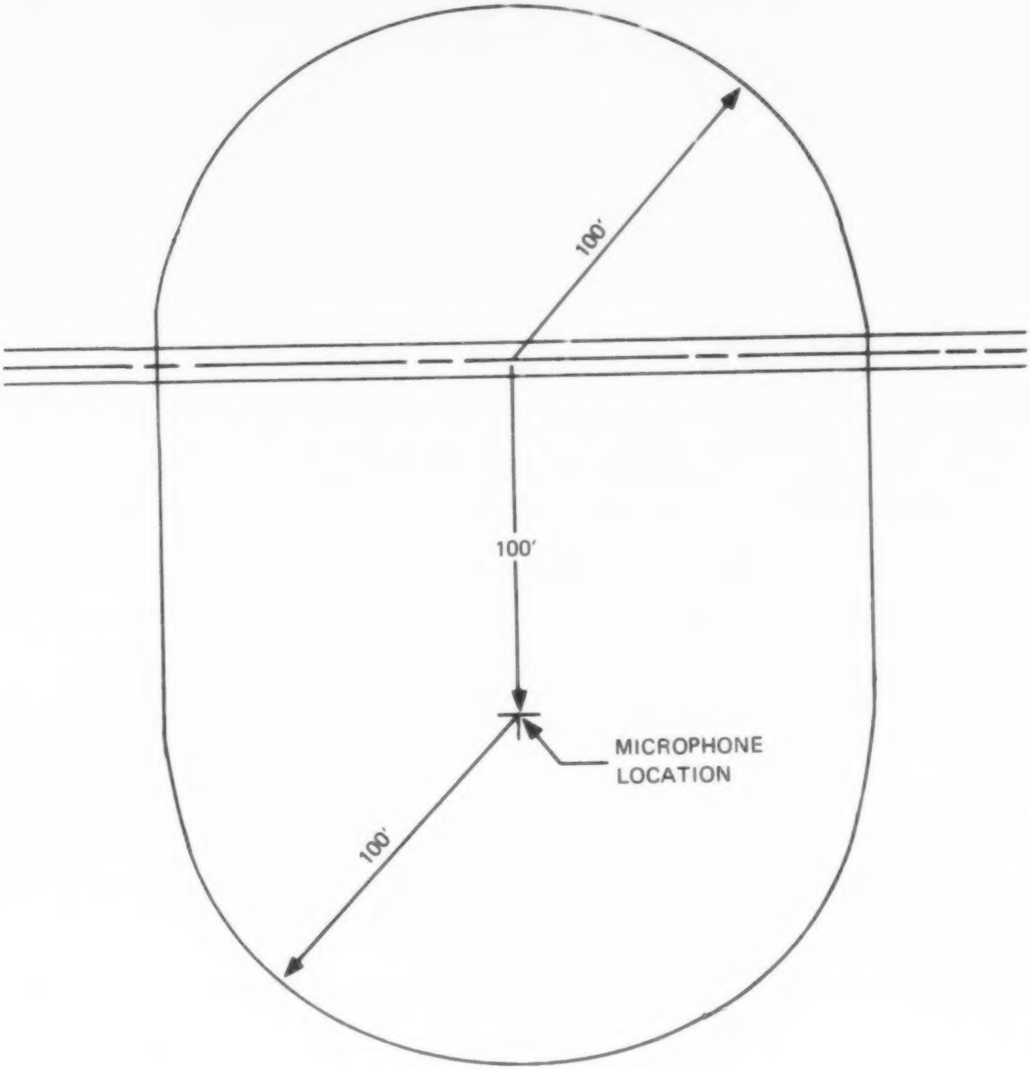
100'
100'
MICROPHONE LOCATION
100'

Figure 6-1. Test Site Clearance Requirement for Locomotive Stationary, Locomotive Passby, and Rail Car Passby Tests

(c) Ground cover such as vegetation, fenceposts, small trees, telephone poles, etc., shall be limited within the area in the test site between the vehicle under test and the measuring microphone such at 80 percent of the top at least one rail along the entire test section of track be visible from a position 4 feet above the ground at the microphone location; except that no single obstruction shall account for more than 5 percent of the total allowable obstruction.

(d) The ground elevation at the microphone location shall be within plus 5 feet or minus 10 feet of the elevation of the top of the rail at the location in-line with the microphone.

(e) Within the test site, the track shall exhibit less than a 2 degree curve or a radius of curvature greater than 2,865 feet (873 meters). This paragraph shall not apply during a stationary test. The track shall be tie and ballast, free of special track work and bridges or trestles.

(f) Measurements shall not be made during precipitation.

(g) The maximum A-weighted fast response sound level observed at the test site immediately before and after the test shall be at least 10 dB(A) below the level measured during the test. For the locomotive and rail car pass-by tests this requirement applies before and after the train containing the rolling stock to be tested has passed. This background sound level measurement shall include the contribution from the operation of the load cell, if any, including contribution during test.

(h) Noise measurements may only be made if the measured wind velocity is 12 mph (19.3 kph) or less. Gust wind measurements of up to 20 mph (33.2 kph) are allowed.

201.24 Procedures for the Measurement of Locomotive and Rail Car Noise

(a) Microphone Positions

(1) The microphone shall be located within the test site according to the specifications given in the test procedures of sections 201.24 (b), (c) and (d), and shall be positioned 4 feet above the ground. It shall be oriented with respect to the sources in accordance with the manufacturer's recommendations.

(2) The observer shall not stand between the microphone and the source whose sound level is being measured.

(b) Locomotive Stationary Test (Load Cell Test)

(1) For stationary locomotive tests, the microphone shall be positioned on a line perpendicular to the track at a point 100 feet from the track centerline at the longitudinal midpoint of the locomotive.

(2) The sound level meter shall be observed for thirty seconds after the test throttle setting is established to assure operating stability. The maximum sound level observed during that time shall be utilized for compliance purposes.

(3) Measurement of locomotive noise shall be made with all cooling fans operating.

(c) Rail Car Pass-by Test

(1) For rail car pass-by tests, the microphone shall be positioned on a line perpendicular to the track 100 feet from the track centerline.

(2) Rail car noise measurements shall be made when the locomotives have passed a distance of 500 feet or 10 rail cars beyond the point at the intersection of the track and the line which extends perpendicularly from the track to the microphone location, providing any other locomotives are also at least 500 feet or 10 rail car lengths away from the measuring point. The maximum sound level observed in this manner which exceeds the noise levels specified in Section 201.13 shall be utilized for compliance purposes.

(3) Measurements shall be taken on reasonably well maintained tracks.

(4) Noise levels shall not be recorded if brake squeal is present during the test measurement.

(d) Locomotive Pass-by Test

(1) For locomotive pass-by tests, the microphone shall be positioned on a line perpendicular to the track at a point 100 feet from the track center line.

(2) The noise level shall be measured as the locomotive approaches and passes by the microphone location. The maximum noise level observed during this period shall be utilized for compliance purposes.

(3) Measurements shall be taken on reasonably well maintained tracks.

Section 7

ECONOMIC EFFECTS OF A RETROFIT PROGRAM

The imposition of a railroad locomotive muffler retrofit program, as proposed in the Notice of Proposed Rule Making, elicited several public comment docket submissions that contained technical and economic data that conflicted significantly with that appearing in the original background document. The principal areas of conflict involve disparities in determination of the best available technology as it exists today and the resultant costs of its application.

There is a further complicating factor in that the available space configurations within many locomotives have been altered over the years due to the addition and modification of various locomotive components such as dynamic braking systems and spark arresters. As a result of this practice, there are numerous and diverse locomotive configurations, each possessing specific peculiarities that must be accounted for in a retrofit program. The implications of this diversity of locomotive configurations and the accompanying disagreement concerning available technology and the cost of its application (i.e., labor rates, capital costs of new facilities, etc.) have given rise to cost of compliance figures ranging from the original EPA estimates of $80 to $100 million to industry estimates approximating $400 to $800 million.

The purpose of this portion of the background document is to present the economic analyses that the Agency has performed concerning a locomotive retrofit program:

- The analysis of the economic effects of retrofit as presented in the original background document.

- Subsequent economic cost and impact analyses of retrofit that constitute refinements to the original analysis.

These studies have been unable to reconcile the differences between Agency and the Railroad Industry positions on the economics of retrofit. Although the generation of additional information concerning the availability of technology might allow the Agency to reconcile such widely varying retrofit cost estimates, the collection of such data would be a costly and time consuming process. Further that process may produce a retrofit cost estimate remaining substantially high relative to the resultant public health and welfare benefits, especially since railroad noise has not been identified as one of the major sources of noise in the environment.

Such factors were the major reasons for the Agency decision to remove the retrofit requirement from the final regulation.

INITIAL ECONOMIC ANALYSIS

The Impact on the Railroad Industry

General Impact

The engineering data gathered from discussions with various manufacturers and railroad operating personnel were used to estimate the direct cost of muffler retrofit by locomotive type and manufacturer. The differences in construction between switcher and road locomotives required that these be treated separately. The three categories of direct cost are mufflers, additional hardware, and labor. Since each make of locomotive is unique, it was necessary to make separate analyses of each type. The cost are shown in Table 7-1. The retrofit costs associated with the various types of locomotives are based on the designs of several common types, which make up about 90 percent of the population. For some locomotives, retrofit costs may be significantly higher than the figures shown here. This may be the case, for example, for several hundred units that, although originally conforming to one of the common designs, have been heavily modified during service so that their configurations now present difficult hardware problems to a muffler installer. Also, there are some 1000 older road locomotives manufactured by Alco and Fairbanks-Morse and owned by a total of 22 railroads, the design of which may render muffler installation difficult. The Agency has been advised that these units are, in fact, in the process of being replaced. Thus, this discussion assumes that such units will be retired from service during the compliance period.

TABLE 7-1
MUFFLER COSTS* PER LOCOMOTIVE
(Source: Manufacturers' and Operators' Estimates)

	Locomotive Manufacturer and Type				
Time of Installation	GM Road	GM Switcher	GE Road	Other Road	Other Switcher
New Production	\$3000 (RB) 2500 (TC)	\$200 - 500	\$1500	- - - - -	- - - - -
Muffler Only	1500	200 - 500	1500	1500	500 - 800
Additional Hardware	200 - 500	- - - - -	1500 - 2500	1500 - 2500	- - - - -
Labor @ 5.80/hr	464 - 1163	46	187	187	46
Total	\$2164 - 3163	\$246 - 546	\$3187 - 4187	\$3187 - 4187	\$546 - 846

(RB) = Rootes Blown
(TC) = Turbocharged

The estimates of the direct cost of mufflers and additional materials were gathered from locomotive and muffler manufacturers. The sources of the data on required labor input were locomotive manufacturers, muffler manufacturers, and management personnel of selected railroads.

An hourly wage rate of $5.80 was arrived at by taking total compensation of maintenance personnel as reported in annual Interstate Commerce Commission (ICC) summaries and dividing by total hours worked.* Although this wage rate probably includes some overtime compensation, it may be an accurate reflection of the true labor cost, since some retrofitting may be done at the overtime rate. We assume that the current mix of straight time and overtime will be used in the retrofit program.

No capital costs for maintenance facilities were assigned to the retrofit program. Annual compensation statistics and discussions with the Association of American Railroads indicate that the roads have been generally cutting back their maintenance staff over the last decade, while not necessarily reducing the size of their plant.** Frequently, therefore, excess physical capacity would be available for a retrofit program. In an economic, although not necessarily an accounting sense, such excess capacity can be utilized at zero cost.

The next step was to determine how many of each type of locomotive are in service. The May 1973 issue of *Railway Locomotives and Cars* lists, by railroad, the make and horsepower of each locomotive in service. In most cases, the horsepower of the engine could be used to determine whether it is a switcher or road locomotive. General Motors (GM) produces both a 1500-hp switcher and a 1500-hp road locomotive, but because road locomotives outnumber switchers by about seven to one, we assumed all GM 1500-hp locomotives to be road locomotives. This biased the cost estimates upward by a small amount. Table 7-2 shows the distribution of locomotives by type and manufacturer, both nationally and for each of the three ICC regions.

Total direct cost of the retrofit program was obtained by multiplying the cost per locomotive by the number of locomotives and is given in Table 7-3 in terms of minimum and maximum costs for each region and for the entire nation. Normally, some locomotives would be retired during the compliance period and, therefore, would not incur retrofit costs. (Their replacements would presumably have been quieted at the factory.) This consideration has not been included here, because it is difficult to forecast replacement rates in the light of an endemic shortage of motive power such as presently exists. If we assume, instead, that past retirement rates (about 2000 units per year from 1965 through 1969) are cut in half due to the shortage of locomotives, this will result in 5000 fewer units needing muffler retrofit for a 5-year compliance period and 2000 fewer over a 2-year period. The total cost estimates projected would then be high by about 20 percent and 8 percent for the two compliance periods, respectively.

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* All railroad data presented in this section come from Interstate Commerce Commission, *Transportation Statistics in the U.S.*, (1971) [67] unless otherwise specified.

**Sources in the AAR state that this may not be the case for roads that have recently modernized their plants and that may have divested themselves of some unneeded facilities. In these cases, according to the AAR, the cost of installing or renting the needed plant and equipment may significantly increase retrofit costs. Unfortunately, precise estimates of capital stock in maintenance facilities do not exist.

TABLE 7-2
DISTRIBUTION OF LOCOMOTIVES BY MANUFACTURER, TYPE, AND REGION
(Source: "Railway Motive Power, 1973." *Railway Locomotives and Cars*, **May 1973)**

Manufacturer and Type	Region			
	Total	East (29 Roads)*	South (8 Roads)*	West (22 Roads)*
GM Road	16,155	7,006	2,026	7,123
GM Switcher	2,811	1,462	304	1,045
GE Road	1,930	878	230	822
Other Road	1,737	1,052	289	396
Other Switcher	1,504	734	139	631

*Number of roads in each district obtained from ICC, *op. cit.* Other listings of roads may not tally with this one, due to varying methods of accounting for mergers, subsidiaries, etc.

TABLE 7-3
TOTAL DIRECT COST OF RETROFIT PROGRAM
(Millions of Dollars)

Region	Locomotive Manufacturer and Type					Total
	GM Road	GM Switcher	GE Road	Other Road	Other Switcher	
East						
max.	$22.160	$0.798	$3.676	$4.405	$0.621	$31.660
min.	15.161	0.360	2.798	3.353	0.401	22.073
West						
max.	22.530	0.570	3.442	1.659	0.534	28.735
min.	15.414	0.257	2.620	1.262	0.345	19.898
South						
max.	6.411	0.166	0.963	1.210	0.118	8.868
min.	4.386	0.075	0.733	0.921	0.076	6.191
National						
max.						69.263
min.						48.162

The annual direct costs in Table 7-4 were derived from Table 7-3 by dividing total cost by the number of years allowed to complete the retrofit program. In addition, the annual cost for 2- and 5-year compliance periods is shown as a percentage of the 1971 net operating revenue. It should be noted that we are assuming 2 and 5 years beginning at the time the muffler becomes available. Generally, mufflers will not be available until 2 years after the regulation is promulgated, so that the 2-year program will not be completed until 4 years after promulgation, and the 5-year program until 7 years after promulgation.

It appears that the direct cost of a retrofit program will not constitute a significant burden on the railroads. Total direct cost is invariant with respect to compliance period, although annual cost is not. Annual cost is, therefore, probably a more relevant measure of the financial impact on the railroads.

The direct cost of retrofitting mufflers is only part of the total cost, however. If retrofitting requires that locomotives be taken out of service, and if the railroads have no excess capacity with respect to locomotives, then there will be some loss of revenue. At present, most railroads are operating a full capacity. The number of locomotives has decreased slightly from 1965 to 1973 (from 27,988 to 27,041) although total horsepower did increase from 52 million in 1971 to 55 million in 1973. It appears, therefore, that capacity has remained about constant or has decreased slightly while demand has increased. It seems unlikely that the present high volume of grain shipments will continue beyond a year. Other factors, however, indicate that the current high levels of capacity utilization will probably continue into the future.

One of the developments that will tend to keep rail transportation at a high level of capacity utilization is the "energy crisis." A general fuel shortage favors the railroads over other modes of transportation. An increase in coal output, which seems inevitable, would stimulate rail freight volume. Coal, because of its low value per ton, is hauled almost exclusively by rail.

A further impact of a general fuel shortage would be to potentially degrade the quality and cost of truck transport relative to rail service. Restricted speed limits could induce delays and uncertainties in truck schedules. Fuel price increases would have a greater adverse impact on trucks than on rail, since trucks use 3.2 times as much diesel oil per ton-mile of freight. As a result transportation demand would tend to shift from trucks to rail. The net effect of these considerations is to support the assumption that railroads will be operating at close to full capacity for the next 5 or so years. This means that locomotive downtime due to retrofit may likely result in lost revenues.

One way in which operators may overcome this problem is to buy new locomotives to take the place of those being retrofitted. Such a procedure would virtually eliminate the indirect cost associated with the retrofit. This is an option, however, only if the locomotive manufacturers can produce the extra units. At present, according to locomotive manufacturers, locomotive production is below demand even though production facilities are operating at full capacity. It is reasonable to assume that conditions of motor power shortage relative to demand for transportation will persist throughout the compliance period, resulting in lost revenue when units are removed for retrofit.

The time lost may be significantly reduced by scheduling retrofits during regular locomotive maintenance. Nationally, the average maintenance cycle is 4 years for an intermediate overhaul and 8 years for a heavy overhaul. The length of the cycle for an individual railroad is a function of locomotive mileage. Table 7-5 shows the national average adjusted regionally to reflect different

TABLE 7-4
ANNUAL DIRECT COST OF 2- AND 5-YEAR RETROFIT PROGRAMS

Region	Total Direct Cost (thousands of dollars)				Cost as Percentage of Net Revenue			
	2-Year		5-Year		2-Year		5-Year	
	Max.	Min	Max.	Min	Max.	Min.	Max.	Min.
National	34,632	24,082	13,853	9,633	1.35	0.94	0.54	0.38
East	15,830	11,037	6,332	4,415	2.04	1.42	0.82	0.57
South	4,434	3,096	1,774	1,238	0.82	0.58	0.33	0.23
West	14,368	9,949	5,747	3,980	1.09	0.75	0.44	0.30

TABLE 7-5
AVERAGE MAINTENANCE INTERVAL BY DISTRICT (years)
(Source: 1971 ICC Statistics and Operators' Estimates)

Type of Maintenance	Regional Average Maintenance Interval (Years)*			
	National	East	South	West
Intermediate	4.0	5.5	4.0	3.5
Heavy	8.0	11.0	8.0	7.0

*These figures do not include the effects of deferred maintenance as practiced by some roads in financial distress.

average locomotive miles per year. The maintenance cycle is shortest in the West, where locomotives travel more miles per year and longest in the East, where miles per year are lowest.

An intermediate overhaul generally takes about 2 to 3 days, while a heavy overhaul takes about 14 days. The estimated time required to retrofit a muffler ranges from 3 days for a GM road locomotive to 1 day for a switcher. Table 7-6 shows the number of lost locomotive days charged to retrofit under different conditions. Line 1, for example, gives lost days by type of locomotive if the locomotive is taken out of service specifically for retrofit. One can see that there are no lost days for any type of locomotive if all retrofitting is done during heavy overhaul.

TABLE 7-6
DAYS LOST DUE TO RETROFIT
(Source: Manufacturers' and Operators' Estimates)

Basis of Retrofit*	Locomotive Manufacturer and Type				
	GM Road	GM Switcher	GE Road	Other Road	Other Switcher
If done by itself	3	1	2	2	1
If done during regular intermediate overhauls	1	0	0	0	0
If done during regular heavy overhaul	0	0	0	0	0

*Assumes no lost time due to travel to and from shop and no muffler retrofitting done during emergency repairs.

As is shown, the total lost locomotive time due to muffler retrofits depends on how many locomotives can be treated during the normal maintenance cycle. Table 7-7 shows the expression used to compute total lost days for each line or district. The first term represents the time lost by GM road locomotives undergoing intermediate overhaul. The remaining three terms account for time lost by those locomotives that will not be due for routine maintenance during the compliance period and that, therefore, must be specially called in for muffler retrofit. (Recall from Table 7-6 that, except for GM road locomotives, units undergoing intermediate or heavy overhaul will experience no extra time lost due to retrofitting a muffler.)

The equation in Table 7-7 has been used to compute lost locomotive days for each region. These have been summed to give a national total. The figures are shown in Table 7-8. Two compliance periods are used to illustrate the decrease in lost time with a longer retrofit period. We see from the table that increasing the period from 2 to 5 years results in a decrease of the lost locomotive days per year by 70 percent.

TABLE 7-7
EQUATION FOR TOTAL LOST TIME PER DISTRICT

$$
\begin{aligned}
LT = \; & \left. \begin{aligned}
& \left| N_{GM} \times \frac{1}{2T_m} \times Y \times 1 \text{ day} \right| \\
+ \; & \left| N_{GM} \times \left(1 - \frac{Y}{T_m} \right) \times 3 \text{ days} \right| \\
+ \; & \left| N_{GEO} \times \left(1 - \frac{Y}{T_m} \right) \times 2 \text{ days} \right| \\
+ \; & \left| N_{SW} \times \left(1 - \frac{Y}{T_m} \right) \times 1 \text{ day} \right|
\end{aligned} \right\} \quad \text{for } \left(1 - \frac{Y}{T_m} \right) > 0 \\
= \; & \frac{1}{2} N_{GM} \times 1 \text{ day} \qquad \text{for } \left(1 - \frac{Y}{T_m} \right) < 0
\end{aligned}
$$

where Y = number of years allowed for retrofit

N_{GM} = number of GM road locomotives

N_{GEO} = number of GE and "other" road locomotives

N_{SW} = total number of switchers of all makes

T_m = time interval for "Intermediate" maintenance

TABLE 7-8
LOST LOCOMOTIVE DAYS BY REGION AND COMPLIANCE PERIOD

Compliance Period	Lost Locomotive Days	Region			
		National*	East (29 roads)	South (8 roads)	West (22 roads)
2-year program	Yearly	17,048	9,252	2,143	6,378
	Total	34,096	18,504	4,286	17,048
5-year program	Yearly	2,044	1,129	203	712
	Total	10,220	5,645	1,013	3,562

*Locomotive days lost nationally is not the sum of the three regions, since the national was calculated using an average maintenance cycle and the regional was adjusted to reflect different utilization rates.

A change in the compliance period affects only the number of lost locomotive days. The direct cost of the retrofit program does not change. If we take the total number of lost locomotive days resulting from a 2-year period and assign it the number 1, then the total number of lost days for a 3-year program is 0.76, the total of a 4-year program is 0.52, and the total of a 5-year program is 0.29. As the compliance period is lengthened, lost locomotive days decrease; thus, the indirect cost of the program decreases.

The calculations of lost locomotive days must be translated into dollar costs. A number of problems arise in calculating the value of a locomotive. First, should a distinction be made between road locomotives and switchers? It seems desirable to treat the transportation revenue earned by rail service as being earned by both road and switch engines, since the lack of either (if both are used to full capacity) would cause a reduction in service. We have therefore assumed that each has the same value per day.

Secondly, what value should be assigned to a locomotive-day? If all roads are operating at full capacity, then removing a locomotive causes a daily loss of revenue amounting to the value of one locomotive-day. A locomotive-day is thus evaluated at the value of the average product. This technique is further justified in capital theory, which states that the value of a piece of capital is the present value of its discounted future stream of earnings; that is,the present value of the marginal product.

Given the conditions just stated, the value of a locomotive-day was calculated by taking total transportation revenue and dividing by the total number of locomotive days available. Table 7-9 shows these calculations nationally and regionally. Table 7-10 gives estimates of the indirect costs of a 2- and 5-year retrofit program by incorporating the lost locomotive-days from Table 7-8 and the value of a locomotive day from Table 7-9. Note that the shorter the compliance period, the larger the total indirect costs. This is a function of the increase in the number of lost locomotive-days as the compliance period is shortened.

TABLE 7-9
REGIONAL ANNUAL REVENUE PER LOCOMOTIVE DAY

	Region			
	National	East	South	West
Total tranportation revenue (millions of $)	$12,417	$4,497	$2,121	$5,799
Transportation revenue per locomotive day ($)	1,251	1,186	1,256	1,304

TABLE 7-10
ESTIMATED LOST REVENUE DUE TO RETROFIT
(Thousands of Dollars)

Region	2-Year Program		5-Year Program	
	Per Year	Total	Per Year	Total
National	21,982	43,963	2,557	12,785
East	10,973	21,946	1,338	6,690
South	2,692	5,383	254	1,270
West	8,317	16,634	928	4,640

Table 7-11 arrives at the annual net retrofit cost by combining the direct and indirect costs and subtracting the reduction in operating costs that would occur as a result of a reduction in traffic. Cost reductions were determined from the ICC detailed accounts and include the following:

Account No.	Description
365	Dispatching Trains
367	Weighing, Inspection, and Demurrage Bureaus
368	Coal and Ore Wharves
371	Yard Conductors and Brakemen
373	Yard Enginemen
374	Yard Switching Fuel
382	Train Enginemen
383	Train Fuel
387	Trainmen
388	Train Supplies and Fuel
395	Employees' Health and Welfare Bureaus

The estimates of cost reductions used here are much lower than those used by the ICC.* They have claimed that 80 percent of costs are out of pocket or variable costs. This might be true if railroads were curtailing service in the face of falling demand. Variabel cost may constitute 80 percent of total cost, but the situation dealt with here is an unplanned reduction in capacity in the face of full utilization of equipment. Under these circumstances, it seems unlikely that the railroads would curtail other operations but rather that they would attempt to offset locomotive shortages by changes in labor and equipment usage patterns. In addition, if there are adjustment costs and since the cutback in capacity is temporary, the railroads would be expected to respond differently from a situation in which the reduction was anticipated to be longer. Table 7-12 gives the total net cost of the 2- and 5-year programs. Again, it points up the cost differential associated with different compliance periods. Much of the computed retrofit cost is the result of lost revenue to the railroads. Figure 7-1 shows the breakdown of annual cost into direct and indirect components for compliance periods of 2 to 5 years.

The annual costs shown in Table 7-11 are best understood in the context of total operating revenue for each region. Table 7-13 shows that the eastern roads would pay a higher percentage of total total revenue toward a retrofit program than would the other regions.

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*See U.S. Interstate Commerce Commission, Bureau of Accounts, *Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs.* St. 7-63, Washington, D.C., 1 November 1963 and U.S. Interstate Commission, "Rules to Govern the Assembling and Presenting of Cost Evidence." Docket No. 34013,321 I.C.C.

TABLE 7-11
ANNUAL NET COST OF RETROFIT
(Thousands of Dollars)

Direct Cost	National	East	South	West
2-year program				
max	$34,632	$15,830	$4,434	$14,368
min	24,082	11,037	3,096	9,949
5-year program				
max	13,853	6,332	1,774	5,747
min	9,633	4,415	1,238	3,980
Indirect Cost				
2-year program	21,982	10,973	2,692	8,317
5-year program	2,557	1,338	254	928
Reduction in Operating Costs				
2-year program	4,964	2,748	555	1,856
5-year program	597	335	53	207
Net Cost				
2-year program				
max	51,650	24,055	6,571	20,829
min	41,100	19,262	5,233	16,410
5-year program				
max	15,813	7,335	1,975	6,468
min	11,593	5,418	1,439	4,701

TABLE 7-12
TOTAL NET COST OF RETROFIT PROGRAM
(Thousands of Dollars)*

Compliance Period	National		East		South		West	
	Max	Min	Max	Min	Max	Min	Max	Min
2 years	103,300	82,200	48,110	38,524	13,142	10,466	41,658	32,820
3 years*	95,221	74,121						
4 years*	87,143	66,043						
5 years	79,065	57,965	36,675	27,090	8,875	7,195	32,340	23,505

*These represent linear interpolations of the 2- and 5-year programs.

TABLE 7-13
ANNUAL RETROFIT COST AS A PERCENTAGE OF 1971 TOTAL OPERATING REVENUE

Compliance Period	National		East		South		West	
	Max	Min	Max	Min	Max	Min	Max	Min
2 years	0.42%	0.33%	0.53%	0.43%	0.31%	0.25%	0.36%	0.28%
5 years	0.13%	0.09%	0.16%	0.12%	0.09%	0.07%	0.11%	0.08%

*Net operating revenue is defined as transportation revenue minus variable transportation costs. Subtracting rents, taxes, and interest payments from net operating revenue gives net operating income or profit from freight operations.

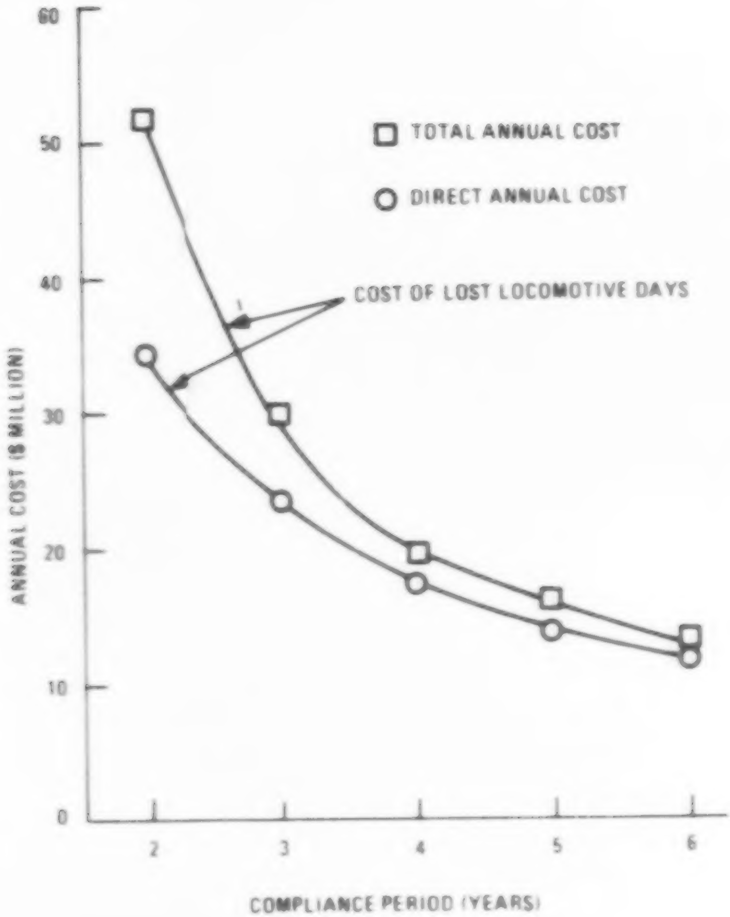

Figure 7-1 Cost of Retrofit Program as a Function of Compliance Period

Annual retrofit cost as a percentage of net operating revenue* gives the best indication of the rail industry's ability to pay for a retrofit program (see Table 7-14). Retrofit constitutes a small percentage of net operating revenue both nationally and regionally. As we have seen earlier, however, the eastern railroads will pay the highest percentage of net revenue for the retrofit program. This partly reflects the fact that eastern roads as a group tend to earn less profit than roads in other regions.

TABLE 7-14
ANNUAL RETROFIT COST AS A PERCENTAGE OF 1971 NET OPERATING REVENUE

Compliance Period	National		East		South		West	
	Max	Min	Max	Min	Max	Min	Max	Min
2 years	1.96%	1.56%	2.48%	0.31%	1.22%	0.97%	1.58%	1.24%
5 years	0.60%	0.44%	0.95%	0.70%	0.38%	0.27%	0.49%	0.36%

Bankrupt roads constitute a special subset for which financial and operating problems are substantially different than for normal roads. This subject will be treated elsewhere.

To give a more detailed picture of the industry's ability to pay for a retrofit program, program cost as a percent of net operating revenue has been computed for each Class I railroad (including bankrupt roads but excluding those with negative net revenues). Figure 7-2 shows how the railroads are distributed with respect to cost-to-net revenue ratio. The figure shows that the impact of a 2-year program is much greater than that of a 5-year program.

The Impact on Marginal Railroads

The adverse effects of extra operating costs is greater on firms in financial distress than those that are healthy. This is of concern in the case of the railroads, because a number of them face difficulties in maintaining profitable operations. It is important to estimate the number of railroads that may have trouble paying the cost of a retrofit program even though the magnitudes of the expenses involved in such a program are small relative to other expenses faced by the railroads. (For example, a 30-percent increase in the price of diesel fuel would increase operating costs by roughly $125 million.** This would represent from 2.5 to 12.0 times the annual cost of a muffler retrofit program, depending on the compliance period allowed.)

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*Net operating revenue is defined as transportation revenue minus variable transportation costs. Subtracting rents, taxes, and interest payments from net operating revenue gives net operating income, or profit from freight operations.

**This figure is computed by using as a baseline the total cost of fuel for all Class I railroads in 1971, which was $417 million [67].

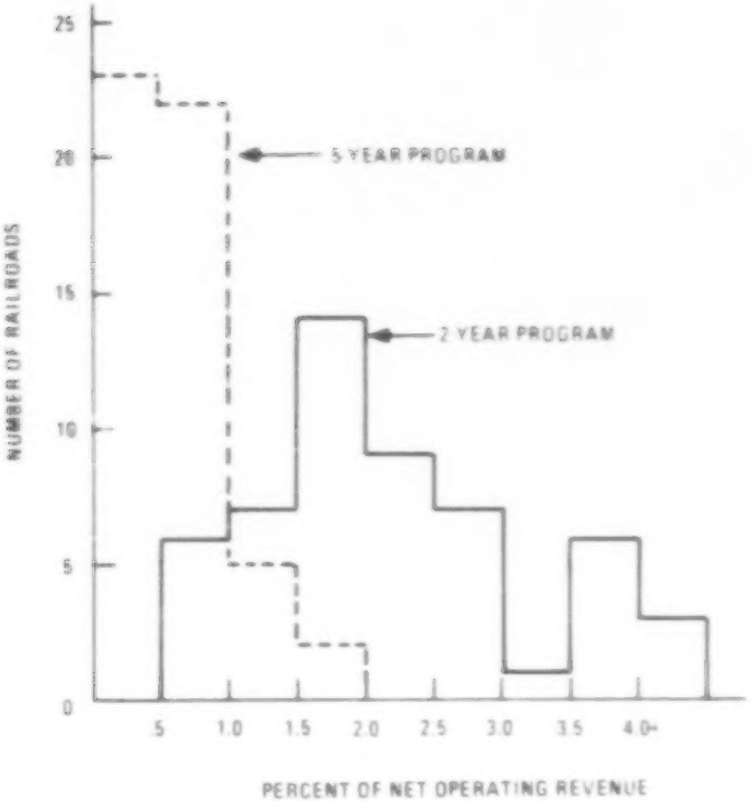

Figure 7-2. Distribution of Railroads by Retrofit Cost as a Percent of Net Operating Revenue for 2- and 5-year Compliance Periods. (Maximum Total Cost Assumed. Bankrupt Roads Included; Made with Negative Net Operating Revenue Excluded.)

This section attempts to gauge the extent of the problem posed in paying for a retrofit program by determining how many railroads are in financial distress. This is done by computing, for each road, several financial ratios that are generally accepted as indicating the financial condition of a business enterprise. A summary of the number *of roads with unfavorable values for each ratio* is then given. This technique does not give a quantitative definition of which railroads cannot afford a retrofit program. At best, it gives a rank ordering. The cutoff value that determines financial distress is arbitrary.

The following financial ratios were computed:

1. Current assets/total assets
2. Operating ratio (operating expenses/operating revenues)
3. Total liabilities less stockholder equity/total assets
4. Income after fixed charges/total assets
5. Retained earnings/total assets
6. Net income/total assets
7. Net income/operating revenue

All bankrupt roads are excluded from this discussion, which is concerned only with roads that have not been declared bankrupt but that may be in financial distress.

In most cases these ratios parallel those used by Edward Altman [1]. Ratios 1 and 2 are measures of the liquidity* of a railroad, while 2, 4, 6, and 7 are measures of profitability and efficiency. Ratio 3 measures solvency.

With respect to ratio 1, the analysis seems inconclusive. A large number of roads had ratios of current to total assets in excess of three standard deviations from the mean. This indicates that the distribution of values of this ratio did not approximate a normal distribution. This being the case, ratio 1 does not constitute a valid indicator of which roads may be in distress.

The analysis of ratio 5 (retained earnings/total assets) indicated that 14 railroads have negative retained earnings, while 2 have zero, showing that these roads lack liquidity. While internal financing may not be important in the rail industry, the negative retained earnings indicate that these roads are drawing down cash reserves.**

The most commonly used measure of profitability is 2, the ratio of operating revenue to operating expenses. Three roads have operating ratios greater than one, indicating that expenses exceed revenue. An additional seven roads have operating ratios more than three standard deviations higher than the mean. Certainly, the three roads and possibly some of the seven must be considered to be in an adverse position. Ratios 6 and 7 are similar measures, in that a road with a negative net income will have a negative ratio for both 6 and 7. Six roads have negative net incomes. In addition, two other roads must be considered to be poor performers as measured by the ratio of net income to total assets (6).

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*Liquidity is the ability of a firm to convert assets into cash.

**This may also represent an insufficient amount of funds allocated to depreciation.

Ratio 4 indicates that nine roads have negative income and two have zero income after fixed charges. These roads are unprofitable by definition. The ratio of total liabilities (less stockholder equity) to total assets (3) appears to have also yielded inconclusive results. One road stands out as being extremely poor by this measure, and there are four other roads for which this ratio is greater than one.

A word of caution should be issued in the interpretation of any ratio that uses total assets. Under the betterment accounting procedure, total assets tend to be inflated. However, to the extent that this bias is uniform throughout the industry, it is possible to compare different roads. It is not possible to compare these ratios with other firms outside the rail industry.

Table 7-15 summarizes the preceding findings with respect to the named ratios. As mentioned before, the table lists worst-performers as indicated by each ratio, the cutoff point being arbitrary. More significant is Table 7-16, which shows how many of the railroads contained in the previous table appear under more than one ratio. Table 7-16 shows that 12 roads are in distress with respect to three or more indicators. It can reasonably be presumed that these 12, at least, could have difficulty in financing a retrofit program.

The Impact on Bankrupt Railroads

Of the 71 Class I line-haul railroads in the United States, 7 are bankrupt: Boston and Main, Central Railroad of New Jersey, Erie Lackawanna, Lehigh Valley, Penn Central Transportation Co., The Reading Co., and Ann Arbor. These seven railroads operate about 20 percent of the locomotives owned by Class I railroads in the U.S. Not surprisingly, the total cost of retrofit for these roads (see Table 7-17) is about 20 percent of the total cost for the entire muffler retrofit program.

These railroads will have difficulty financing the cost of a muffler retrofit program. There is no question that the financial positions of these roads are bad. All seven have negative net income, and are currently meeting their deficits in part by drawing down cash reserves. Many of these roads are currently receiving some form of subsidy, and all are in default on interest payments, bonds, and taxes.

The Impact on Users of Rail Transportation

The effect of a muffler retrofit program may be felt by railroad users in either or both of two ways. First, the possibility exists that the railroads may try to recover their retrofit expenses through a rate increase. Second, the withdrawal of locomotives from service could result in reduced hauling capacity and a consequent decline in the quality of service. Either of these developments would tend to encourage some shippers to go elsewhere for transportation services. This discussion examines the possible magnitude of these effects.

The Effect on Railway Freight Rates

The ability of the rail industry to recapture the cost of a muffler retrofit program depends on the characteristics of the market it faces. The establishment of AMTRAK and the low volume (and high price elasticity) of passenger service probably precludes the railroads from recovering any of the retrofit costs through increases in passenger fares. Rather, increased revenues would be more likely to come from increasing freight rates.

TABLE 7-15

NUMBER OF RAILROADS IN UNFAVORABLE FINANCIAL POSITION RELATIVE TO EIGHT INDICATORS

(For Each Indicator, Railroads Listed in Order of Increasingly Favorable Position)

Indicator	Number of Roads in Unfavorable Position
1. Current assets/total assets	Inconclusive
2. Operating ratio	4 roads greater than 1 (expenses > revenues) 4 roads between 1 and .85
3. Total liabilities (less stockholders' equity)/total assets	3 roads greater than 1 2 roads equal 1 2 roads between .99 and .71
4. Income after fixed charges/ total assets	8 roads negative 1 road zero
5. Retained earnings/total assets	13 roads negative 1 road zero
6. Net income/total assets	4 roads negative 4 roads zero 2 roads positive but less than .011
7. Net income/operating revenue	4 roads negative 2 roads zero 2 roads positive but less than .031

TABLE 7-16
NUMBER OF RAILROADS DESIGNATED AS BEING IN FINANCIAL DIFFICULTY BY ONE OR MORE FINANCIAL INDICATORS

Number of Financial Indicators, N, in Table 7-15	Number of Railroads Appearing under N Indicators in Table 7-15
1	7
2	2
3	6
4	3
5	2
6	1

TABLE 7-17
NET COST OF MUFFLER RETROFIT PROGRAM FOR THE SEVEN BANKRUPT CLASS I RAILROADS

Length of Program	Annual Cost		Total Cost	
	Max	Min	Max	Min
2 Years	$10,569,000	$8,393,000	$21,139,000	$16,786,000
5 years	3,197,000	2,326,000	15,984,000	11,631,000

Freight rate increases must be approved by the ICC. Inquiries to the ICC indicate that the Commission places no *a priori* limits on the magnitude of rate increases that may be requested. It is entirely the railroad industry prerogative to decide if requests for rate increases are to be submitted to cover the costs shown in Table 7-12. Any cost factor could form a legitimate basis for increasing rates to recover costs. Furthermore, the ICC is considering environmental aspects in its rate determination. As a result of litigation involving the environmental effects of various rate structures, the ICC has prepared serveral Environmental Impact Statements showing their concern.*

In summary, there are strong indications that the rate increases that could be requested by railroad companies to defray the costs of noise reduction would fall within the practice of the ICC. No *a priori* bias would be applied by ICC agents, and they could be expected to act with a positive attitude toward the objective of improving the quality of the environment.

To place the level of expenditure and possible freight rate increase in perspective, previous cost increases and subsequent rate increases may be used for reference. In the ICC report served 4 October 1972, in Ex Parte 281, a rate increase for railroad freight was authorized. The railroads claimed in their rate request that expenses had increased $1.312 billion from January 1971 to April 1972. The authorized rate increases were:

● National Average	3.44%**
● East	3.60%
● South	3.10%
● West	3.44%

These increases, if fully applied, would have increased revenue by $426 million; however, the most usual case is that they are not fully applied. The industry estimates that only 85 percent, or $349 million, will actually be realized.***

Since the rate increase of September 10, 1972, costs have risen by $930 million. About 80 percent of this rise has stemmed from wage increases and increased payroll taxes. In light of these higher costs, in April of 1973 the railroads applied for a 5-percent rate increase. The maximum cost of the 2-year muffler retrofit program is about $51 million, which is only 5.5 percent of the $930 million cost increase that led to the request for a 5-percent rate increase. The rail industry claims that if the entire $930 million cost increase is to be recovered, it will require a 7.5-percent increase in rates.****

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*See ICC Docket, Ex Parte 281 and Ex Parte 344F, Supplement 927.

**The National average was calculated by using regional data.

***These figures come from estimates made by the rail industry. They assume that the elasticity of demand is zero--an unlikely situation. The question of elasticity is considered later in this section.

****Again, this estimate assumes that the elasticity of demand for rail service is zero.

The amount of the recoverable costs and the attendant freight rate increase necessary will depend on the elasticity of demand for rail freight.* The annual (maximum) retrofit costs for the 2-year program represent about 0.4 percent of 1971 freight revenue, while the 5-year (minimum) program represents only about 0.1 percent of freight revenue (see Table 7-13).

Data from Friedlaender [47] for 1961 have been used to calculate an overall rail freight demand elasticity of -0.7. Using this elasticity, we can estimate the increase in freight rates necessary to offset the increased costs. The freight increases are shown in Table 7-18. Also shown is the percent these increases would represent of the 1971 average rate per ton-mile, which was $.01594.

TABLE 7-18
RATE INCREASE THAT WOULD ENABLE RAILROADS TO RECOVER RETROFIT EXPENSES

Length of Program	Rate Increase (Cents per Ton-Mile)	Percent of 1971 Average Freight Rate
2-year		
max	.0232	1.46%
min	.0184	1.15
5-year		
max	.0076	0.48
min	.0057	0.36

These rate increases must be interpreted carefully. They were calculated by using demand elasticities derived from 1961 data. Since then, a number of changes have taken place that would probably increase the elasticity of demand for rail service.

- First, the near-completion of the interstate highway system has improved the service rendered by trucks and has reduced operating costs.
- Second, the rise in interest rates has made the cost of holding inventories higher and might have made shippers more sensitive to other service characteristics, causing a downward shift in the demand curve and potentially increasing its elasticity.

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*Elasticity of demand is the ratio of the percent rise in quantity demanded to the percent rise in price. An elasticity coefficient of -0.1, therefore, indicates that a 10-percent price increase would result in a 1-percent decrease in demand.

- Third, shifts among the various commodity classes of freight might have resulted in an increase in the elasticity. For example, if the price elasticity of demand for rail service is higher for mineral ores than for manufactured products and if the share of mineral ores has increased relative to manufactured product, then the overall elasticity would have increased.

We have attempted to make some estimates of the new elasticity, taking into account the shift in the distribution of commodities. The results should be interpreted only as tentative. We have used the 1961 elasticities for each commodity group but have weighted tham by the 1971 commodity distribution.

Data from Friedlander [47] have been used to obtain the following elasticities for the five major commodity groups:

Commodity	Elasticity
Agriculture	0.5
Animal products	0.6
Products of forests	0.9
Products of mines	1.2
Manufacturing and other	0.7

These figures represent the pre-1964 commodity classification used by the ICC. To determine the current elasticity of demand, we used these commodity group elasticities and weighted them by the current distribution of freight within these groups. These weighting factors are:

Commodity	Elasticity
Agriculture	.097
Animal products	.0002
Products of forests	.144
Products of mines	.420
Manufacturing and other	.387

To determine the distribution, it was necessary to take the current freight classifications and assign them to one of these categories.

The overall elasticity was calculated to be -0.953, significantly more than the estimate of -0.7 obtained from Friedlander's data. Even more interesting is the distribution of elasticities by district. To arrive at these estimates, it was necessary to assume that the rate per ton-mile for each of the 1971 commodity classifications was equal for each of the three districts. Although this is not the case, we believe the errors to be small. The estimated elasticities are:

East	-0.99
South	-0.95
West	-0.83

These figures indicate that the eastern roads, which are in financial difficulty, would have the most trouble recovering the cost of a retrofit program. The western roads, which, as a group, are the most profitable, would easily recover the cost of a retrofit program.

Given the energy crisis, however, even this tentative analysis may not be valid. As discussed earlier, railroads use less energy per ton-mile of freight moved than trucks, pipelines, or airlines. As a result, railroads would be impacted less than these other competitive modes by increases in fuel costs.

It is not possible to accurately predict at this point, the effects of any rate increases the ICC might grant to the railroads to recover the costs of a retrofit program. The possible effects of increased rates on demands for rail service are directly related to the energy situation. If competitive modes of transportation (i.e., trucks, pipelines, and airlines) are more severely impacted by increased fuel rates, the fact that railroads increased their rates to cover the costs of a retrofit program might well be insignificant.

The Effect on Quality of Service

It has previously been shown that, to accomplish a retrofit program within a compliance period of 5 years or less, some locomotives would likely have to be withdrawn from service in addition to those undergoing maintenance by the usual schedules. The number of locomotive-days taken up in this manner is given in Table 7-19 in absolute numbers and as a percentage of locomotive days available. If, under normal conditions, the railroads are operating at or near full capacity, then the figures shown in the table represent the upper bound of lost freight hauling capability.

TABLE 7-19
ANNUAL LOCOMOTIVE DAYS TAKEN UP BY RETROFIT PROGRAM

Compliance Period	Locomotive Days	Region			
		National	East	South	West
2-year	Absolute	17,048	9,252	2,143	6,378
	% of Total Available	.194%	.225%	.197%	.174%
5-year	Absolute	2,044	1,129	203	712
	% of Total Available	.023%	.027%	.0187%	.0195%

The impact of decreased hauling capability on the various commodities shipped by rail depends on how the railroads react to the capacity decrease. There are two ways in which demand for rail service can be made to equal the available supply: non-price rationing or price rationing.

In the case of non-price rationing, the railroads could simply allow service to decline in quality while maintaining the same rates. The resulting delays and uncertainties in the transporation network would have differential impacts on the various commodities being shipped. Those items highly sensitive to the quality of service will tend to be diverted to other modes of transportation. Commodities in this category are high-value products, for which transportation charges are a small fraction of total value, and perishables.

Price rationing involves raising the price of service (with the approval of the ICC) to decrease demand to the level of the new, reduced capacity. Such a policy would affect commodities sensitive to freight rates. Examples of these would be mineral ores and semi-finished products. Such goods would tend to be shipped by other modes, or the quantity shipped would be reduced.

The probable magnitude of the effect of price rationing can be estimated. Table 6-19 shows that, in the worst case, capacity would decline by about 0.2 percent nationally. Assuming that the elasticity of demand for rail transportation is about -0.7 gives a price rise of 0.28 percent necessary to effect the required reduction in demand. This amounts to an average increase of 0.004 cents per ton-mile relative to the 1971 average freight rate. This increase is fairly small, so minimal changes in transportation patterns may be expected as a result of the retrofit program.

Summary and Conclusions Concerning Initial Economic Analysis

Impact on the Railroad Industry

Cost. The cost of a muffler retrofit program is highly sensitive to the compliance period allowed. Maximum total cost for a 2-year program is estimated to be $103 million. Allowing 5 years for compliance would reduce the total cost to approximately $79 million.

Change in net revenues. The impact of a 2-year program would be to reduce overall Class I railroad annual net operating revenues by about 2 percent.

Effect on prices. For the railroads to recover the expense of a retrofit program would require an average freight rate increase of approximately .023 cents per ton-mile in the 2-year case and .008 cents per ton-mile in the 5-year case. These figures represent, respectively, 1.46 percent and 0.48 percent of the 1971 average freight rate.

Effect on capacity. A 2-year retrofit program would result in an annual loss of as many as 17,000 locomotive-days, or about 0.2 percent of the total available, for the duration of the programs. This would drop to about 0.02 percent for a 5-year program.

Impact on marginal railroads. Approximately a dozen railroads are in financial difficulties, as indicated by the computed values of a number of standard financial ratios. These roads may have difficulty in raising the funds necessary to pay for a retrofit program.

Impact on bankrupt railroads. Seven roads are presently bankrupt, and may not be able to finance a retrofit program without an external source of funds. The total program cost for these roads would be $21 million for a 2-year program and $16 million for a 5-year program.

Impact on Users of Rail Services

Prices. Increases in freight rates would tend to encourage some shippers to seek alternate modes of transportation. This would occur primarily among shippers of commodities having prices sensitive to transportation cost, such as semi-finished products. It is not likely, however, that the small rate increases foreseen by this study would cause any major hardships or dislocations.

The energy crisis may make any railroad rate increases insignificant compared with competitive modes of transportation, which would be more severely impacted by rising fuel costs.

Quality of service. A decrease in the hauling capacity of the railroads may result in the diversion of some freight to other modes of transport. Which commodities would be affected depends on how the railroad would decide to reduce demand to the level of supply. If rates were raised, the effect would be the same as discussed in the previous paragraph. If rates remained constant but shipping delays were allowed to develop, commodities sensitive to transit time (such as perishables) would be most affected. Such diversions, however, will tend to be localized and on a small scale in view of the small reductions in capacity anticipated.

SUBSEQUENT ECONOMIC COST AND IMPACT ANALYSES

The Cost of Retrofitting Mufflers on Locomotives

The costs of installing mufflers on operating diesel railroad locomotives fall into three categories:

1. Initial direct cost, consisting of the costs of materials (including the muffler and other hardware), labor, capital (including the cost of new shop facilities if required), and testing.
2. Initial indirect cost, consisting of the net revenue lost due to taking locomotives out of service for retrofit and the costs of developing suitable muffler designs.
3. Continuing cost, consisting of the annual costs of maintaining mufflers and costs of extra fuel consumed by locomotive having mufflers.

This discussion contains detailed estimates of each of these cost categories. These estimates are refinements of the cost estimates contained in the original Background Document, refinements made on the basis of questions raised in EPA Docket No. ONAC 7201002, and information submitted to that docket.*

The costs projected here are computed for muffler designs based on the analyses presented in Appendices G and H. That is, the basic muffler designs are arrangements of expansion chambers and baffles, with no internal sound-absorbing materials or unconventional chamber configurations. The mufflers are presumed to effect a 10-dB reduction in exhaust noise level while meeting manufacturer warranty restrictions on additional backpressure (5-in. H_20 for turbocharged engines, 21-in. H_20 for Rootes blown). It is also presumed that the mufflers are designed to fit the space currently available within or above the engine hood and to require no rearrangement of major internal components such as dynamic brake assemblies. The feasibility of designing mufflers within these constraints has been analyzed in Appendices G and H.

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*Costs presented here are as of 1973, the last year for which complete data are available, unless otherwise stated. The effect of inflation would be to raise the absolute costs by 8 to 10 percent per year, but the percentage impacts would remain unchanged.

Initial Direct Costs

The initial direct cost of a muffler retrofit program is determined by:

- The cost of materials, including mufflers and other required hardware.
- The hourly cost of labor.
- The man-hours of labor required for retrofit.
- The cost of capital equipment.
- The cost of performing noise tests.

Cost of Materials. The primary material cost incurred in a muffler retrofit program is the cost of the muffler itself. Since no locomotive exhaust mufflers have been manufactured on a production basis, there are no data on the actual cost of such units. Therefore, the probable cost of such units will be estimated on the basis of the current price of mufflers designed for similar diesel engines, but not built for locomotive applications (i.e., without size restrictions). The example chosen is the Maxim M-31 silencer designed for a turbocharged 16- or 20-cylinder GM 645 series diesel engine. The 1975 list price of this muffler is $2206, with discounts of up to 40 percent available for volume purchases. This muffler averages 20-dB attenuation over the band ranging from 37.5 to 5000 Hz, measures 14.3 ft long by 4.5 ft in diameter, and weighs 3200 lb. This unit is substantially larger and more effective than would be required for locomotive exhausts, which need only about a 10-dB noise reduction. Therefore, the price shown represents a highly conservative (i.e., overstated) estimate of the price of mufflers for locomotives. We have chosen $1500 as a typical price to be paid for a muffler to be installed on a turbocharged locomotive. This figure agrees with the $1500 price price estimated for EMD series 20, 30, 35, 39, 40, and 45 locomotives by the Association of American Railroads [20].

The $1500 price applies only to turbocharged locomotives, which, according to the analyses of Appendix G can have mufflers installed directly on the turbocharger outlet stack. Rootes-blown road locomotives, on the other hand, typically have a space problem when mufflers are added to the exhaust line. The most effective way of quieting such units, according to the Appendix G analysis, is to enlarge the existing segmented exhaust manifold collector into a single manifold-muffler. It is estimated that the cost of this will be the cost of a replacement manifold, which is $3690 [20], plus $1000 to cover internal baffles and resonance chambers that may be required. These figures give a total cost of approximately $4700 for muffling a Rootes-blown road locomotive.

Switchers, which are Rootes-blown, do not have the space limitations of road locomotives, since they have room for mufflers over their low hoods. Switchers, it is claimed, need their low hoods for visibility, and mufflers would interfere with this visibility. The first half of this statement is only partly true, as shown by the frequent use of old high-hooded GP7 and GP9 locomotives as switchers. The second statement is not true at all, since the volume of the muffler can be distributed over the length and breadth of the hood so that the vertical dimension need not be large. For example, a muffler having the same volume as the Maxim MSA-1 for a 12-cylinder EMD 645E engine (42.4 ft) could be built to have dimensions of 5 ft in width, 10 ft in length, and less than 1 foot in height. This muffler would easily fit over the hood of an EMD SW1500 switcher with minimum visibility interference.

The cost of switcher mufflers, therefore, is based on the price of a Maxim MSA-1 muffler spark arrester designed for a 12-cylinder Rootes-blown GM 645E engine, such as is used on an EMD SW1500 switcher locomotive. The 1975 list price of this muffler is $848, with discounts available for quantity purchases. Therefore, $700 is selected as the 1973 price for switcher mufflers.

Some turbocharged road locomotives will require hardware changes to allow installation of the muffler.* EMD turbocharged units will require heat shielding for dynamic brake cables, larger turbocharger removal hatches, and heavier turbocharger exhaust ducts. General Electric units will require new roofs that can accommodate the mufflers. The material cost for these hardware changes is shown in Table 7-20.

TABLE 7-20
HARDWARE MODIFICATIONS AND MATERIAL COSTS FOR TURBOCHARGED ROAD LOCOMOTIVES

Make	Modification Required	Materials Price
EMD	Apply new turbocharger exhaust duct	$ 800[1]
	Replace turbocharger removal hatch	300[1]
	Apply heat shields to dynamic brake cables	25[1]
	TOTAL	$1135
GE	Apply new hood roof	$2000[2]

[1] Source: Garin, p. 12 in AAR, 1974 [20].

[2] Source: Estimate of P. Baker, General Electric Co., as stated to M. Rudd, BBN, August 1973. The estimate assumes that the cost of body modification would include only the purchase of a new, center cab section; the original side doors would be used again.

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*Rootes-blown locomotives will require no modifications, because the muffler consists simply of a larger manifold, having no effect on the locomotive internal arrangement or cab design.

Hourly Cost of Labor. Computed here is the average cost of labor in railroad maintenance for the year 1973, the last year for which statistics are available. The cost of labor consists of wages (including overtime compensation), fringe benefits, and payroll taxes. Because these quantities vary depending on the quality of labor, the average must be weighted for the prevailing mix of skilled craftsmen and other employees. The average cost of supervisory labor must also be included.

Presented first is the average hourly wage rate for skilled and other workers. These were obtained by dividing the total 1973 compensation by the total hours worked for each of the two labor categories. The result is shown in the third column of Table 7-21 for the three U.S. railroad regions.

The next step is to determine, for each labor category, the average wage rate times an appropriate multiplier for fringe benefits and payroll taxes. AAR Sources [5] indicate that this multiplier is 1.16 for all regions. The result is shown in the last column of Table 7-21.

TABLE 7-21
AVERAGE 1973 HOURLY WAGE RATE FOR SKILLED AND OTHER WORKERS

Labor Category	Region	Compensation[1] ($ millions)	Hours Worked[1] (million)	Average Wage Rate, including Overtime ($/hr)	Average Hourly Labor Cost ($/hr)
Skilled	East	457.9	69.3	6.61	7.67
	South	162.7	25.1	6.49	7.53
	West	458.2	68.9	6.45	7.72
Other	East	91.7	17.9	5.12	5.94
	South	39.9	8.3	4.83	5.60
	West	112.6	22.2	5.07	5.88

[1] Source: Betts, 1973.

The third step is to combine the skilled and other labor costs for each railroad region, weighting the average according to the appropriate labor mix. For all Class I railroads in 1973, the skilled crafts represented 84 percent of the hours paid for under the category Maintenance of Equipment and Stores.* The remaining 16 percent were other laborers. The resulting weighted average hourly labor costs for each region are shown in the first column of Table 7-22. To obtain a national average, the regional figures are weighted according to the percentage of locomotives found in the last column in Table 7-22.

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*Source: ICC Statement A-300, 1973.

TABLE 7-22
1973 WEIGHTED AVERAGE HOURLY LABOR COST DEVIATION

Region	Weighted Average Hourly Labor Cost[1] ($/hr)	Hourly Weighting Factor[2] (% of Locomotive Population)	National Weighted Average Hourly Labor Cost ($/hr)
East	7.47	36	7.41
South	7.22	18	
West	7.43	46	

[1] Source: Computation in text.

[2] Source: Computed from ICC Transportation Statisitcs, 1973.

[3] Excludes supervisory labor. Add $0.51 per hour to account for supervision; see text.

The computation so far does not include supervision. Supervisory personnel make up about 6 percent of the labor input in the Maintenance of Equipment and Stores account, and their average compensation was about 15 percent higher than the average of all workers in that sector. Multiplying 0.06 × 0.15 × $7.41 gives a figure of $0.51 per hour, which is added to the average labor cost to obtain a total of $7.82 per hour.

Labor Required for Retrofit. The estimates of required retrofit labor given in the Background Document were based on informal discussions with railroad maintenance personnel. Since that time, the Association of American Railroads has submitted detailed information to the docket on this topic. A summary of the labor hours by work item and the total labor cost per locomotive is given in Table 7-23.

Cost of Capital Equipment. The muffler retrofit program will be carried out primarily in railroad shops. If the maitenance shops do not have enough unused capacity to perform the work, they will have to acquire new facilities. In the latter case, the cost of such facilities would be charged to the retrofit program.

Peabody and Associates [57] have estimated that the curent level of excess capacity in rail diesel shops, unadjusted for possible retirements, is 14.3 percent. They calculated this figure by taking the level of expenditures adjusted to constant dollars for each year from 1969 to 1973 and by taking the year in which expenditures were highest as defining the level of full capacity. An annual productivity increase of 1.0 percent was allowed for.

In addition to using total maintenance expenditures as an indicator, excess capacity can be estimated by examining the labor hours in that sector; labor hours represent a physical measure of input. If it is assumed that the ratio of capital to labor required to maintain locomotives did not

TABLE 7-23
LABOR MAN-HOURS AND TOTAL LABOR COST FOR MUFFLER RETROFIT PROGRAM

Locomotive	Item	Man-Hours per Locomotive[1]	Cost @ $7.92/hr
Turbocharged road	Exchange turbocharger duct and turboremoval hatch	33	$260
	Apply heat shields for dynamic brake cables	9	73
	Apply muffler	9	73
	TOTAL	51	$406
Rootes-blown Road	Replace manifold with manifold silencer	9	$ 73
Switcher	Apply muffler	9	$ 73

[1] Source: Obtained by dividing AAR labor cost for each item (Garin, pp. 12, 16, and 17 in AAR 1974) by the AAR "labor rate" of $14.00. The AAR "labor rate" includes shop overhead; i.e., cost of capital equipment, which is treated separately in this development.

change from 1969 to 1973, then any decline in labor hours worked must be reflected in an equivalent percentage of the capital equipment standing idle (barring retirements of equipment).

During the period from 1969 to 1973, the labor input in the maintenance sector decreased by 13 percent. If one allows for a 1 percent annual increase in productivity in both capital and labor, then the predicted 13 percent excess shop capacity is increased to about 17 percent. The labor required for the proposed retrofit program is less than 1 percent of the labor hours currently used in the Maintenance of Equipment and Stores sector.

One other factor to consider is the possible retirement of capital over the period 1969 to 1973. A sample of 10 roads, which was conducted by Peabody Associates, indicated that 95 percent of the capacity in diesel shops that existed in 1969 is still in existence today. This figure reflects the conservative assumption that all retirements reduced capacity while all new investment had no effect on capacity. A more realistic appraisal would be obtained from net investment (i.e., investment minus depreciation) less retirements. However, even with these conservative assumptions and the assumption that the sample of 10 roads gave a true picture of the industry, there will be sufficient capacity to complete the retrofit program, and further acquisition will be unnecessary.

Cost of Testing. The cost of installing mufflers on locomotives includes testing each unit to determine whether it needs treatment. Two types of stationary tests are:

1. Load cell test. The generator output is connected to a bank of resistors that absorb the electrical output, so that the engine may be run at full throttle under load while stationary. This is the only test for units that do not have dynamic brakes capable of absorbing the generator output. Disadvantage: stationary load cells found in railroad yards may not be in an acoustically acceptable environment.

2. Self-load test. The generator output is dissipated through the dynamic brake resistor grid. Advantage: this test can be performed at any location. Disadvantage: on EMD locomotives, a separate fan cools the resistor grid; noise from this fan may bias the test results.

A problem may exist in providing enough acoustically acceptable load cells to test locomotives that do not have dynamic brakes. One solution: railroads can buy portable load cells. These are commercially available and can be built large enough to accommodate locomotive generator outputs (typically, 2500 kW maximum at 60 Vdc). They can be mounted on trucks and transported to acoustically acceptable sites near yards or shops accessible to locomotives. Units of this size are not generally available, but discussions with load cell suppliers indicate that no design or manufacturing problems would prevent their being supplied. The projected price for such a unit is $100,000 at current cost levels.*

The total cost of acquiring portable load cells can be estimated by assuming that

- Half the locomotive population will be tested by this means. Note that all GE locomotives (15% of the population) can be tested under self-load, and it is assumed that stationary cells can accommodate the remaining 35%.

- An average of one locomotive per day will be tested by each cell for two years. Note that in actual use each cell would spend several days in transit, followed by several days measuring locomotives at each site.

The number of load cells needed would therefore be obtained by computing

$$\frac{(0.5 \times 27{,}000 \text{ locomotives})}{(2 \text{ years} \times 365 \text{ days per year} \times 1 \text{ locomotive per cell per day})}$$

which gives an answer of 18.49, or approximately 20 cells. The total cost of $2,000,000, divided by 27,000 locomotives, comes to $74 per unit.

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*Source for information on load cells: conversations with D. Partridge, Simplex Co., Springfield, Illinois.

Another piece of equipment that will be required for testing will be a sound level meter. Type 2 meters, with fast and slow readings, are available, with calibrators, at about $200 each. The precise number required is not known, but it is assumed to be 500 (i.e., one meter for every 54 locomotives). The total cost would be $100,000.

The labor used in testing each locomotive would consist of one technician for approximately 2 hours.* Using the average of the skilled labor costs derived above (Table 7-21) and allowing for 6 percent supervisory time at a 15 percent labor cost premium, an average labor cost of $8.18 per hour is obtained, or $16.36 per locomotive.

Summary of Initial Direct Costs. Table 7-24 summarizes the direct cost of locomotive retrofit. Note that the subtotal figure represents costs incurred only by those locomotives actually retrofitted, or approximately 75 percent of the population.

TABLE 7-24
INITIAL DIRECT COSTS OF RETROFITTING EXHAUST MUFFLERS TO LOCOMOTIVES

Cost Areas	Locomotive Type			
	EMD Road, RB	EMD Road, TC	GE Road	Switcher
Muffler	$4690	$1500	$1500	$700
Additional Hardware		1135	2000	
Labor	73	406	406	73
Subtotal	$4763	$3041	$3906	$773
Testing	91	91	91	91
Total	$4854	$3132	$3997	$864

Initial Indirect Costs

Two elements comprise indirect initial costs: (1) cost net revenue due to locomotive downtime and (2) cost of developing suitable muffler designs. The first of these categories will be analyzed in two phases: the cost of locomotive downtime and the expected number of lost locomotive-days.

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*It is assumed that protable load cells will be located in areas easily accessible by locomotives in the course of their normal operations. There will, therefore, be negligible cost for locomotive transit time or down time or for crew time.

Cost of Locomotive Down time. The marginal value of a locomotive-day is the extra net revenue the locomotive would have generated had it been available for use. This is defined as the gross revenue per locomotive-day less the locomotive daily operating expenses. If there is excess capacity in the locomotive fleet, then the revenue generated by an extra locomotive is zero; that is, down time is free, since there are idle locomotives. At present, however, the railroads' hauling capacity is under considerable strain. The value of marginal revenue is, therefore, taken to be the average per revenue per total locomotive in the fleet.* Dividing the total locomotives (27,117) times 365 days per year into 1973 gross operating revenues ($14.2 billion) gives an average revenue figure of $1438 per locomotive-day.

To show that this is a correct procedure an example is presented. If retrofit were to be performed over a 4-day period in which railroads were closed, the lost revenue would be the revenue that would have been earned over those 4 days. The total lost revenue could be expressed in terms of revenue per locomotive times the number of locomotives. If revenue per locomotive were to be derived by including only serviceable locomotives and then were to be multiplied by the total number of locomotives, the estimated revenue loss would exceed the actual revenue loss. Of course, lost revenue per serviceable locomotive could be calculated and then multiplied by the number of serviceable locomotives. Thus, computations of total revenue loss must be done using either serviceable locomotives or total locomotives consistently in both the numerator and the denominator. Either method gives the same answer, as long as one is consistent. Total locomotives were chosen, since it avoids using one population for lost revenue and another for direct cost.

To obtain the true cost to the railroad, this figure must be reduced by an amount equal to the expenses saved by not having to operate the locomotive. In the Background Document, this was done by identifying those ICC cost accounts that would be reduced and by calculating the level of these reductions (see Table 7-11). The ratio of expenses to revenue thus derived was 4964/21,982 = .226. The AAR submission to the docket (p. 62) [20] uses a ratio of expenses to revenue of 39,826,000/64,978,000 = 0.61 (Welsh, p. 62) [20]. The $39,826,000 figure does not appear on that page but can be calculated by subtracting from lost revenue, $64,978,000, net losses of $25,152,000). (While the AAR claims that 0.61 is the ratio used in the Background Document, it is not.) However, the 0.61 figure is consistent with the ICC evaluation of railroad expenses, which are claimed to be about 80 percent out-of-pocket expenses (i.e., variable). Using the ICC figure and a 1973 operating ratio (total operating expenses divided by total operating revenue) of 79.3, the ratio of variable expenses to revenue is 63.4. In the subsequent calculations, 0.61 is used since this is the ratio AAR uses and it is consistent with the ICC percent-variable (i.e., out of pocket) calculations. Using $1438 as as the value of a locomotive-day, the reduced expenses equal $877 (i.e., 0.61 × $1438), and the net cost of a locomotive-day is $561.

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*Some concern may arise over whether one should divide gross revenues by the total number of locomotives (27,117) or the number of serviceable locomotives (26,245). The choice is arbitrary, as long as the same figure is used to compute both revenue per locomotive and total lost revenue. See subsequent discussion.

Number of Lost Locomotive-Days. Table 7-25 shows the EPA estimate of the time lost per locomotive during retrofit. This table is based on Table 7-25 of the original Background Document, which, in turn, was derived from conversations with railroad maintenance personnel. The EPA figures are contrasted in the table with the elapsed-time estimates provided by the AAR in their submission to the docket (Garin, p. 16) [20]. The difference arises because of the large amount of extra work entailed in the AAR projected retrofit program, work involving the relocation of dynamic brakes, fans, and cooling system pipes. If this type of work (which is necessitated by the AAR space-inefficient muffler design) is discounted, the two estimates are not dissimilar.

The actual number of days lost by the total fleet depends on how frequently locomotives undergo major repair. As shown in Table 7-25, some time is saved if mufflers can be retrofitted

TABLE 7-25
DAYS LOST DUE TO RETROFIT

Estimator	Basis of Retrofit[1]	Locomotive Manufacturer and Type			
		EMD Road, RB	EMD Road, TC	GE and Other Roads	Switcher
EPA[2]	If done by itself	3	3	2	1
	If done during regular intermediate overhauls	1	1	0	0
	If done during regular heavy overhaul	0	0	0	0
AAR[3]	Done by	2.5 - 5[4]	3 - 3.5	2.5 - 5[4]	3 - 3.5

[1] Assumes no lost time due to travel to and from shop and no muffler retrofitting done during emergency repairs.

[2] Source: EPA Original Background Document, June 1974.

[3] Source: AAR, 1974.

[4] Depends on whether extended-range dynamic brakes are present.

while other repairs are being made. The EPA original Background Document gave an average maintenance interval of 4 years for intermediate overhauls and 8 years for heavy overhauls.*

The annual total of lost locomotive-days for the nation is now computed, assuming a 2-year compliance period, and the annual cost of those lost days. In any given year, one-eighth of all locomotives undergo heavy repairs,and another eighth undergo intermediate overhaul. The number of lost days is therefore given by

$$\begin{aligned} LT = N_{ER} \times & \left[\left(\frac{3}{4} \times 3 \text{ days} \right) + \left(\frac{1}{8} \times 1 \text{ day} \right) \right] \\ & + N_{GE} \times \left(\frac{3}{4} \times 2 \text{ days} \right) \\ & + N_{SW} \times \left(\frac{3}{4} \times 1 \text{ day} \right) , \end{aligned}$$

where

LT = lost time in locomotive-days,

N_{ER} = number of EMD road locomotives,

N_{GEO} = number of GE and other road locomotives,

N_{SW} = number of switchers.

The total number of locomotives in each category is shown in Table 7-26. It is assumed, in the interest of being conservative, that no locomotive retirements will take place during the retrofit period. Inserting the figures in the table into the preceding expression gives a total of 51,840 locomotive-days lost. This total is based on the assumption, however, that all locomotives would be retrofitted, whereas in fact only 75 percent would actually be retrofitted. Therefore, the number of lost locomotive-days would be 38,880 (51,840 times 0.75). At $561 per day (the cost of one lost locomotive-day), the cost per year to the industry would be $10.9 million, or $21.81 million over the 2-year complaince period.

Cost of Developing Mufflers. At present, mufflers designed for railroad service conditions are not commercially available. It may be assumed that it will be necessary to develop, fabricate, and test several prototypes of each basic design before the designs can be approved for service. In the absence of detailed designs, it is not possible to plan such a development program and project its costs. However, we can make some reasonable assumptions to estimate the cost.

It is assumed that six basic muffler designs are to be developed and tested, with several models based on each design. If the cost of the development and test program for each design is $500,000, the total effort would cost $3 million.

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*Peabody and Associates (1974) report an average interval of 7.3 years for overhaul. They do not discriminate between intermediate overhauls, in which the cylinders are changed in place and the bearings are renewed, and heavy overhauls, which involve lifting off the cab and rebuilding the locomotive components as necessary [57].

TABLE 7-26
NUMBER OF LOCOMOTIVES BY TYPE (1973 AVERAGE)

Type of Locomotive	Number
EMD Rootes-blown Road	7786
EMD Turbocharged Road	9579
GE and Other Road	4381
Switchers	5371
Total	27,117

*Source: *Railway Locomotives and Cars*, May 1974. Due to a small discrepancy in the total number reported in this reference relative to the ICC total, the figures in the reference were scaled downward by a factor of 0.985 to give a total of 27,117.

Continuing Costs

Two types of operating costs may be affected by muffler retrofit. First, mufflers will probably need to be maintained. Second, the backpressure imposed on the diesel engine by the muffler may result in degraded fuel economy and, thus, higher fuel costs.

Maintenance Requirements. The original Background Document does not explicitly identify extra maintenance costs due to muffler retrofit. The original analysis noted that mufflers are similar in construction, materials, and service conditions to the exhaust manifolds that presently exist on locomotives. There is no evidence to show that exhaust manifolds fail in service or require other than occasional attention. Accordingly, it was assumed that the extra effort required to maintain mufflers would be small compared to the other identified costs.* A highly conservative estimate would be to assume that mufflers will require replacement at every major overhaul, or approximately every 8 years. If $1600 is allotted for parts and labor per locomotive for a locomotive population of approximately 27,000, with 75 percent having mufflers, an average annual expenditure of $4.1 million per year is calculated.

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*This is the case, for example, with mufflers on heavy diesel trucks. Conversations with truck fleet operators indicate that service failures of such mufflers are virtually unknown,and that an occasional patch weld is the most maintenance required.

Fuel Costs. An increase in the back pressure on an engine exhaust line increases the work the engine must do to pump exhaust gases through the line. The result is a decrease in overall engine efficiency. There are, however, no test data available on the magnitude of this effect for large diesel engines. General Electric estimates that "If forced to run with 20°F higher pre-turbine temperatures, the increase in fuel consumption would be on the order of 1 percent [70]. The AAR (1974) also cites the 1-percent figure, although without any supporting data. Therefore, 1 percent will be used as a conservative figure appropriate to line-haul operation. If 1 percent is multiplied times the 1972 railroad fuel consumption of 3690 million gallons (for line-haul freight and passenger operations; source: ICC statistics [67, 68]), we obtain an extra 36.9 million gallons of diesel oil consumed per year. At the 1975 wholesale price of $0.30 per gallon for diesel fuel, this amounts to an extra $11.1 million per year.

Summary of Locomotive Retrofit Costs

Tables 7-27 and 7-28 show the breakdown of initial and annual costs for the entire locomotive retrofit program. The total parts and labor costs were obtained by multiplying 0.75 (the fraction of locomotives needing retrofit) by the numbers of locomotives in each category as shown in Table 7-26, and then by the direct costs for each category as given in Table 7-24. Testing cost was obtained by multiplying $91 from Table 7-24 by the total number of locomotives. As before, it was assumed that no locomotives would be retired during the retrofit period.

Economic Impact of Muffler Retrofit

In the public docket for the proposed noise regulation on diesel electric locomotives, a number of economic issues have been raised, including the availability of labor, the impact on railroad financial viability (which includes the impact on freight volume), and the impact on product prices as a result of possible freight rate increases. This discussion provides an analysis of these and other issues associated with the economic impact of muffler retrofit. Included are:

- An evaluation of possible labor shortages in the rail sector.
- A discussion of alternate measures of financial impact on the railroads.
- A description of the current economic condition of U.S. Class I railroads, along with a discussion of the issue of the differential impact of fuel costs on railroads and trucks.
- Consideration of the question of freight diversion.
- Consideration of the impact of retrofit on freight rates and on the U.S. economy.

TABLE 7-27
SUMMARY OF INITIAL LOCOMOTIVE RETROFIT COSTS FOR A 2-YEAR PROGRAM
(Figures in $ Millions)

Initial Direct Costs (2 yrs)		
Parts and Labor	$65.63	
Testing	2.47	
Total		$68.10
Initial Indirect Costs (2 yrs)		
Lost Locomotive Time	$21.81	
Muffler Development	3.00*	
Total		$24.81
Total Initial Costs (2 yrs)		$92.91

*Estimate based on conservative assumptions; no data available. See Text.

TABLE 7-28
SUMMARY OF ANNUAL COSTS OF LOCOMOTIVE RETROFIT FOR A 2-YEAR PROGRAM
(Figures in $ Millions Per Year)

Initial Costs (Direct and Indirect; obtained from Table 7-27)	$46.45
Continuing Costs (annual average)	
Extra Maintenance	4.05*
Extra Fuel	11.10*
Total	$15.15

*Estimate based on conservative assumptions; no data available. See text.

Labor Supply

The ability of the railroads to perform a retrofit program depends on whether the required labor is available. To odentify whether a labor shortage exists, a means for testing for labor shortages must first be established.

Firms adjust to labor shortages first by increasing the number of hours worked per employee and then, if the increased demand for workers is sustained, by adding new employees. Thus, in the short run, the number of hours rises, and in the long run, the number of employees rises. Increases in hours worked and number of employees are therefore indicative of short-term and long-term labor shortages, respectively. The hours that should be considered are hours worked, including straight time and overtime. One should not consider only overtime, since the distribution of hours between overtime and straight time is, in part, a function of institutional arrangements (e.g., union contracts). Thus, a rise in overtime does not necessarily indicate a labor shortage.

The last 4 years have constituted a period of decreasing labor hours and decreasing employment in the Maintenance and Equipment and Stores sector (ICC designation). The number of employees, the number of hours for which employees were paid (including vacations and holidays), the total hours worked, and the average hours worked per employee all declined from 1970 to 1973. Comparing 1970 to 1973, average hours paid per employees increased, while hours worked per employee decreased, indicating an increase in paid time off. Average overtime hours per employee decreased each year from 1970 to 1972 and then increased from 1972 to 1973, but were still below the 1970 level. These trends are summarized in Figure 7-3.

The Maintenance of Equipment and Stores sector does not exhibit any of the characteristics of a labor market in which a labor shortage exists. However, the rise in overtime from 1972 to 1973 could indicate shortages in specific categories in labor; i.e., the rise in overtime could be the result of an increase in overtime of specific categories of labor, and offsetting reductions in overtime and lay-offs in other categories of labor could have caused average hours worked to remain constant and overtime hours to rise. This would indicate a shortage in specific trades. To determine whether this has been the case, trends in hours worked and workers employed in specific trades shall be examined.

In the 25 categories of labor listed under Maintenance of Equipment and Stores, one cateogry (helper apprentice, 65*) had more employees in 1973 than in 1970. Average hours worked per employee increased for the same time period in three categories (electrical workers B & C, 59, 60; skilled trades helper, 64). The adjustment in hours and employment may have begun more recently. Labor demand would have reached a low point and then increased during this period.

From 1972 to 1973, average hours worked per employee increased in five categories (inspectors, 52; boilermakers, 55; electrical workers B & C, 59, 60; skilled trades helpers, 64; and gang foreman in stores, etc., 69). In three cases, average hours per employee remained unchanged, and in the rest, they declined. During the same period (1972 to 1973), employment increased in five categories: general, assistant general, and department foreman, 50; electirical workers B, 60; helper apprentices, 65; regular apprentices, 66; and classified laborers, 70. In two of the remaining 25 categories, employment was virtually unchanged, and in all others it decreased.

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*Numerical designations refer to ICC Standard Accounts.

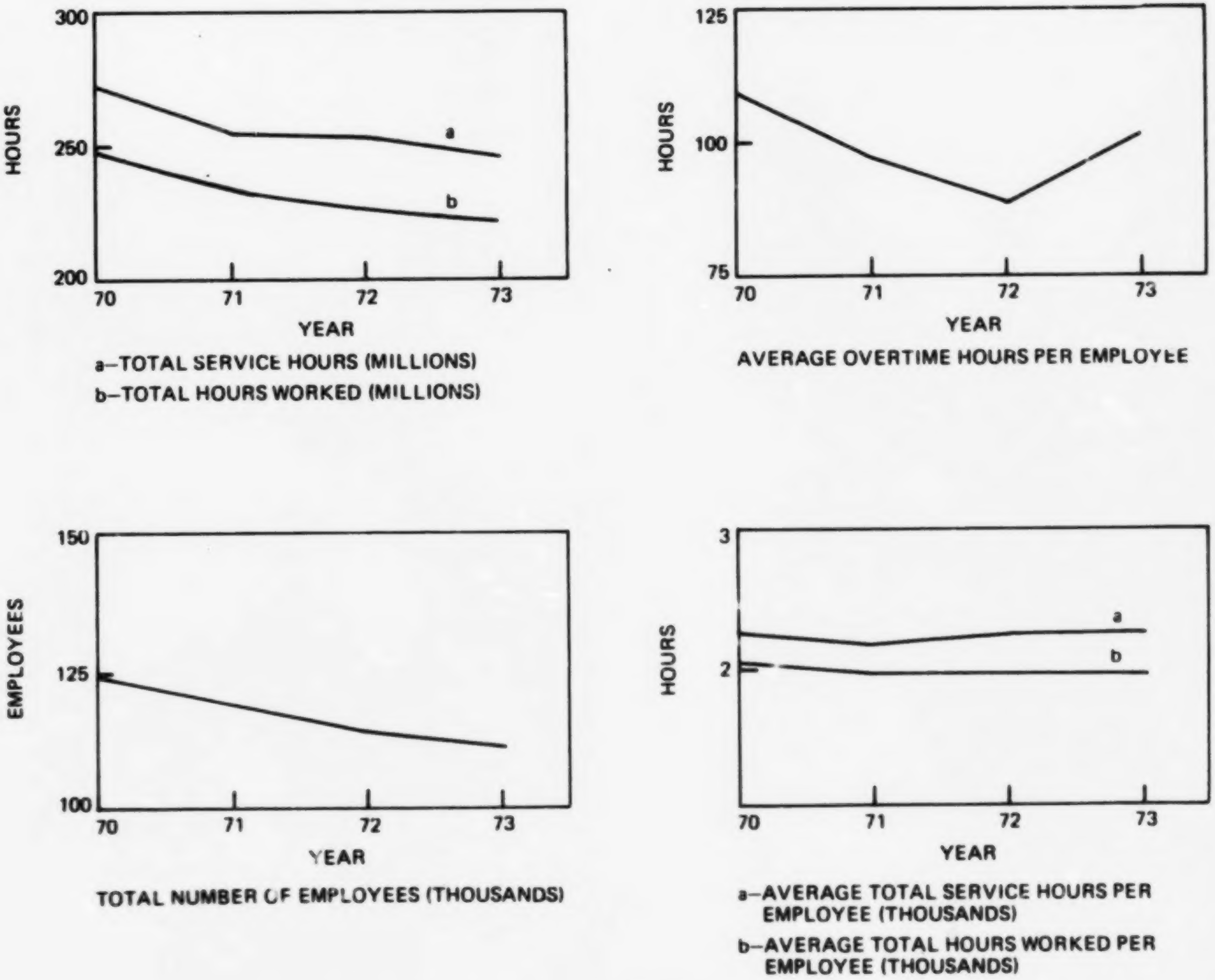

Figure 7-3. Patterns in Maintenance of Railroad Equipment and Stores

Thus, the following categories in which there appear to be some recent increases in labor input (either through increased hours or increased employment) can be identified:

- Foreman (general, etc.), 50
- Inspectors (equipment, shop, electrical, etc.), 52
- Electrical workers B & C, 59, 60
- Skilled trades helpers, 64
- Helper apprentices, 65
- Regular apprentices, 66
- Gang foreman (stores, etc.), 69
- Classified laborers (shops, engine houses, etc.), 70.

In the 16 categories not listed, the labor input has been reduced by reducing hours and reducing employment, indicating that there is not a shortage of labor in these 16 categories and that, in fact, they could probably be expanded by increasing hours.

In four categories (50, 65, 66, 70), average hours per employee decreased, while employment increased. If the 1973 hours worked per employee were increased to the 1970 levels, the increase in total hours worked would be 2 to 3 percent.

Category 50 is supervisory labor, which is not likely to be affected by a muffler retrofit program. If it should be, however, then the current labor input could be increased by 3 percent (of the 1973 total) by increasing hours worked to the 1970 levels. Category 70 (classified laborers) is an unskilled occupation that could be increased through new hires or by increasing hours worked to the 1970 levels, thus increasing the labor input by 2 percent (of the 1973 level).

Categories 65 and 66 are not homogenous, since they include helper and regular apprentices, respectively, in different trades. It would be inappropriate, therefore, to consider an overall increase in hours, particularly if the distribution of apprentices in different trades has changed over time. Increases in the number of apprentices from 1972 to 1973 do indicate the industry is training journeymen, which in turn may indicate an inability to hire trained workers in the skilled trades. The number of apprentices has only increased by 99 from 1972 to 1973; the 1973 level is still below the 1970 levels.

Hours worked have increased from 1972 to 1973 for:

- Inspectors, 52
- Electrical workers B & C, 59, 60
- Skilled trades helpers, 64
- Foreman (stores, etc.), 60.

The average hours worked per employee in categories 59 and 60 in 1973 exceeded the 1970 levels. However, the number of employees in Category 59 was 11 percent (111 employees) fewer in 1973 than in 1972, but in Category 60, 12 percent more (15 employees). In Categories 52, 64, and 69, the average hours worked per employee was less in 1973 than in 1970. Since 69 is a supervisory classification for stores and ice and reclamation and timber treating plants, this group would be unaffected by a retrofit program.

TABLE 7-29
LEVELS OF EMPLOYMENT AND AVERAGE HOURS WORKED IN 1970 AND 1972 COMPARED TO 1973

Categories	1970 Level of Employment	1970 Average Hours Worked per Employee	1972 Level of Employment	1972 Average Hours Worked per Employee	Increase in 1973 Hours Worked if the Hours were Increased to the 1970 Level but Employment Remained at 1973 Level (hrs per employee)
50	larger	larger	smaller	larger	3% (67)
52	larger	larger	larger	smaller	2% (45)
59	larger	smaller	larger	smaller	None (73 exceeds 70)
60	larger	smaller	smaller	smaller	None (73 exceeds 70)
64	larger	larger	larger	smaller	2% (29)
65	smaller	larger	smaller	larger	3% (64)
66	larger	larger	smaller	larger	1% (20)
69	larger	larger	larger	smaller	4% (80)
70	larger	larger	smaller	larger	2% (33)

Table 7-29 shows, by category, the increases in 1973 hours worked that would occur if the hours were increased to the 1970 level per employee: 64 would increase labor input by about 2 percent, and 52 would increase by about 2 percent.

There seems to be a strong indication that a labor shortage does not exist and that hours could be increased to provide the labor required for a retrofit program. The exceptions to this are:

- The increase in training identified by apprentice categories 64 and 65 (one might also assume that skilled trades helpers, 64, is an entry level job that can provide skilled workers through upgrading)
- The electrical workers B & C, 59 and 60. The fact remains that the number of apprentices in 1973 is less than the 1970 level.

As shown in Table 7-30, the total hours required for a retrofit program are small compared to the total hours worked in the maintenance sector:

TABLE 7-30
MAN-HOURS REQUIRED FOR LOCOMOTIVE RETROFIT

Locomotive Type	Man-Hours Per Locomotive	Locomotives in Service	Total Man-Hours
EMD (RB)	9	7786	70,074
EMD (TC)	51	9579	488,529
GE & Other Road	51	4381	223,431
Switcher	9	5371	48,339
Total Hours			830,373
Annual total hours over 2 years			415,186.5
Annual total hour as a percent of 1973 hours covered in Maintenance of Equipment and Stores Sector.*			0.19%

*Total hours worked in Maintenance of Equipment and Stores in 1973 was 221.04 million hours.

Impact on Railroad Revenue and Profits

The question considered in this section is the appropriate base to use for comparing the total cost of retrofit. A retrofit program has both a short- and a long-term impact on railroads. The short-run impact occurs over a 2-year period and then disappears. Some costs continue after retrofit (e.g., increased fuel costs) and must be considered separately.

Since the nonrecurring costs of a retrofit program cover only a 2-year period, the appropriate base against which to compare these costs is net revenue. A firm will sustain short-term losses so long as it covers its variable costs, and net revenue is a measure of the excess of revenue over variable costs. Net operating income measures the excess of revenue over variable plus fixed costs and is, therefore, indicative of the firms long-term ability to pay. (Note that in no case should recurring costs be compared to net income after taxes, since taxes will be reduced by increased costs.)

The total annual nonrecurring costs are $46.45 million. The 1973 net operating revenue of railroads was $3,097.68 million. The short-term costs of a retrofit program would therefore represent 1.50 percent of the 1973 net revenue per year over each of the 2 years. As pointed out in Table 7-28, the increased fuel costs would be $11.10 million. During the first 2 years (while retrofit is being carried out), the increased fuel costs would be 25 percent of this for the first year and 75 percent for the seond year. These percentages represent the average portion of the fleet that will have completed the retrofit program in the first and second years, respectively. Thus, $2.78 million is added to the first year and $8.33 million to the second year retrofit costs, making the first year $49.23 million and the second year $54.78 million.

It is assumed that no extra maintenance (beyond the retrofit itself) will be necessary in the first 2 years. Thus, the first year costs are 1.59 percent and the second year costs are 1.77 percent of net operating revenue.

The recurring expanse of $15.15 million per year represents 1.83 percent of the 1973 net railway operating income before Federal income taxes. (The 1973 net income before Federal income taxes was $830.7 million).

Financial Impact

In general, the adverse effect of extra operating costs is greater on firms in financial distress than on healthy firms. This is of particular concern in the case of the railroads, a number of which face difficulties in maintaining profitable operations. The extent to which this is a problem is illustrated by the seven lines that are presently bankrupt. It is clearly important to estimate the number of railroads that might have trouble paying the cost of a retrofit program.

It should be noted that it is impossible to predict whether a firm already in difficulty will be bankrupt as a result of this (or any other) externally imposed cost, for two reasons. First a declaration of bankruptcy is not necessarily related to a firm's financial position at any one moment but is based instead on the management's opinion of the firm's viability in the long term. Thus, a short-term nonrecurring expense would not necessarily have an impact. Second, the magnitudes of the expenses involved in such a program are small relative to other problems faced by the railroads.

While it is unlikely that the cost of retrofitting mufflers would actually cause bankruptcy, it is still true that roads in financial trouble may have difficulty affording the program cost. This section attempts to gauge the extent of this problem by determining how many railroads are in financial distress. This will be done by computing, for each road, several financial ratios that are generally accepted as indicating the financial condition of a business enterprise. A summary of the number of roads that have unfavorable values for each ratio is then provided. Of course, this technique cannot provide a quantitative definition of which railroads cannot afford a retrofit program. At best, it gives a rank ordering. The cutoff value that determines financial distress is entirely arbitrary.

The following financial ratios were computed:

1. Current assets/total assets.
2. Operating expenses/operating revenues.
3. Total liabilities less stockholders' equity/total assets.
4. Income after fixed charges/total assets.
5. Retained
6. Net income/total assets.
7. Net income/operating revenue.

In most cases these ratios parallel those used by Edward Altman [1]. Ratios 1 and 5 are measures of the liquidity* of a railroad, while 2, 4, 6, and 7 are measures of profitability and efficiency. Ratio 3 measures solvency.

With respect to ratio 1, the analysis seems inconclusive. A large number of roads had ratios of current-to-total assets in excess of three standard deviations from the mean. This indicates that the distribution of values of this ratio did not approximate a normal distribution. This being the case, ratio 1 does not constitute a valid indicator of which roads may be in distress.

The analysis of ratio 5 (retained earnings/total assets) indicated that 14 railroads have negative retained earnings, while 2 have zero, showing that these roads lack liquidity. While internal financing may not be important in the rail industry, the negative retained earnings indicate that these roads are drawing on cash reserves.**

The most commonly used measure of profitability is operating ratio 2, the ratio of operating-revenue-to-operating-expense. Three roads have operating ratios greater than 1, indicating that expenses exceed revenues. An additional seven roads have operating ratios more than three standard deviations higher than the mean. Certainly, the three roads and possibly some of the seven must be considered to be in an adverse position. Ratios 6 and 7 are similar measures, in that a road with a negative net income will have a negative ratio for both 6 and 7. Six roads have negative net incomes. In addition, two other roads must be considered to be poor performers as measured by the ratio of net-income-to-total-assets (6).

Ratio 4 indicates that nine roads have negative income and two have zero income after fixed charges. These roads are unprofitable by definition. The ratio of total liabilities (less stockholder equity)-to-total-assets (3) appears to have also yielded inconclusive results. One road stands out as being extremely poor using this measure, and there are four other roads for which this ratio is greater than 1.

A word of caution should be issued in the interpretation of any ratio that uses total assets. Under the betterment accounting procedure, total assets tend to be inflated. However, to the extent that this bias is uniform throughout the industry, it is possible to compare different roads. It is not possible to compare these ratios with other firms outside the rail industry.

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*Liquidity is the ability of a firm to convert assets into cash.

**This may also represent an insufficient amount of funds allocated to depreciation.

Tables 7-31 through 7-37 show the railroads that had unfavorable values for each of the seven financial indicators described above. The railroads are rank-ordered for each ratio, the railroad with the most unfavorable ratio being listed first.

Freight Diversion as a Result of Differential Impacts of Fuel Costs

The manner in which fuel prices will affect the distribution of freight between rail and truck can be demonstrated using the graph in Figure 7-4.

TABLE 7-31
RATIO 1–CURRENT ASSETS/TOTAL ASSETS

Ratio	Railroad	ICC No.
.06	Missouri-Kansas-Texas	47
.06	Pittsburgh & Lake Erie	68
.06	Texas Pacific	67
.07	Bangor & Aroostook	7
.07	(B) Lehigh Valley	42
.08	(B) Reading	59
.08	(B) Erie Lackawanna	30
.08	Central Vermont	14
.08	Western Maryland	70
.09	Long Island	43

(B) Indicates bankrupt road.

TABLE 7-32
RATIO 2–OPERATING EXPENSES/OPERATING REVENUE

Ratio	Railroad	ICC No.
143.4	Long Island	43
114.1	Pennsylvania Reading Seashore	57
104.7	Pittsburgh & Lake Erie	58
103.4	Bangor Aroostook	7
92.0	(B) Ann Arbor	3
92.9	Lake Superior & Ishpeming	41
90.3	Grand Trunk Western	35
89.5	(B) Lehigh Valley	42
89.5	Western Maryland	70
88.0	(B) Penn Central	56
87.1	(B) Reading	59
84.8	(B) Boston & Maine	9

TABLE 7-33
RATIO 3–TOTAL LIABILITIES LESS STOCKHOLDER EQUITY/TOTAL ASSETS

Ratio	Railroad	ICC No.
11.11	Pennsylvania Reading Seashore	57
2.33	Grand Trunk Western	35
2.02	Central Vermont	14
1.10	(B) Central Railroad of New Jersey	13
1.00	Georgia	33
1.00	Missouri-Kansas-Texas	47
.99	Clinchfield	21
.89	(B) Erie Lachawanna	30
.75	(B) Penn Central	56
.73	(B) Ann Arbor	3
.71	(B) Lehigh Valley	42

TABLE 7-34
RATIO 4–INCOME AFTER FIXED CHARGES/TOTAL ASSETS

Ratio	Railroad	ICC No.
-.30	Pennsylvania Reading Seashore	57
-.28	Long Island	43
-.12	Grand Trunk Western	35
-.06	(B) Penn Central	56
-.06	(B) Ann Arbor	3
-.05	(B) Lehigh Valley	42
-.04	(B) Central Railroad of New Jersey	13
-.04	(B) Reading	59
-.02	(B) Boston & Maine	9
-.02	Western Maryland	70
-.02	Delaware	23
-.01	Fort Worth & Denver	32
-.01	Chicago Rock Island & Pacific	19
.00	(B) Erie Lackawanna	30
.00	Chicago, Milwaukee, St. Paul & Pacific	18

TABLE 7-35
RATIO 5–RETAINED EARNINGS/TOTAL ASSETS

Ratio	Railroad	ICC No.
-.31	Pennsylvania Reading Seashore	57
-.29	Long Island	43
-.15	Grand Trunk Western	35
-.13	(B) Penn Central	56
-.06	(B) Ann Arbor	3
-.05	(B) Lehigh Valley	42
-.04	(B) Central Railroad of New Jersey	13
-.04	(B) Reading	59
-.03	Chicago, Milwaukee, St. Paul & Pacific	19
-.03	(B) Boston & Maine	9
-.03	Baltimore & Ohio	6
-.02	Delaware & Hudson	23
-.02	Western Maryland	70
-.01	Chicago & Northwestern	17
-.01	Chicago, Rock Island & Pacific	19
-.01	Kansas City Southern	40
-.01	Burlington Northern	10
-.01	Fort Worth & Denver	32
.00	(B) Erie Lackawanna	30
.00	Monon	49

TABLE 7-36
RATIO 6–NET INCOME/TOTAL ASSETS

Ratio	Railroad	ICC No.
-.28	Long Island	43
-.26	Pennsylvania Reading Seashore	57
-.11	Grand Trunk Western	35
-.04	(B) Penn Central	56
-.04	(B) Ann Arbor	3
-.03	(B) Lehigh Valley	42
-.02	(B) Reading	59
-.01	(B) Central Railroad of New Jersey	13
-.01	(B) Boston & Maine	9
.00	Fort Worth & Denver	32
.00	Chicago, Rock Island & Pacific	19
.00	Monon	49
.00	Delaware & Hudson	23
.01	Missouri-Kansas-Texas	47
.01	Western Mayland	70

TABLE 7-37
RATIO 7–NET INCOME/OPERATING REVENUE

Ratio	Railroad	ICC No.
-7.24	Pittsburgh & Lake Erie	58
-6.87	Bangor & Aroostook	7
-1.97	Grand Trunk Western	35
-1.22	(B) Lehigh Valley	42
-1.06	(B) Ann Arbor	3
- .85	(B) Penn Central	56
- .40	(B) Reading	59
- .14	(B) Boston & Maine	9
- .14	(B) Central Railroad of New Jersey	13
.00	Fort Worth & Denver	32
.00	Chicago, Rock Island & Pacific	19
.03	Monon	49
.03	Delaware & Hudson	23

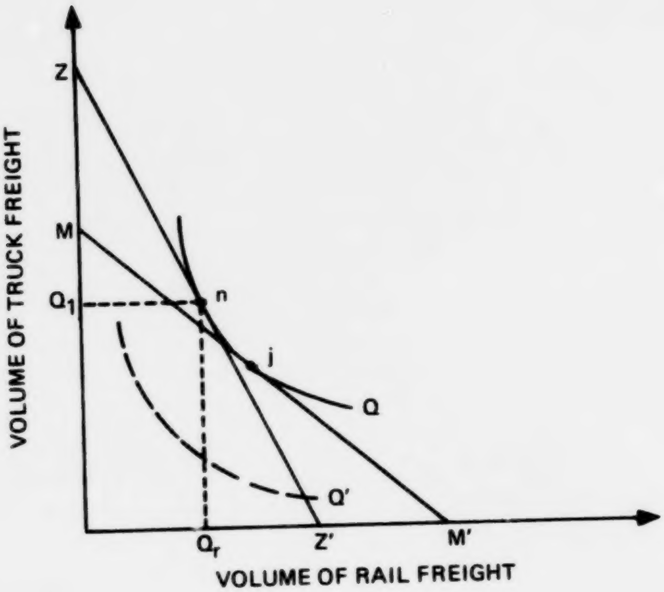

Figure 7-4. Effect of Fuel Prices on Distribution of Freight

Line Q represents the quantity of freight service (truck and rail) necessary to produce a given level of output (given level of GNP). Any point on Q (and the combination of rail and truck freight it represents) is a possible equilibrium position. Line ZZ' represents the volume of rail and truck freight that can be carried for a constant dollar expenditure on freight. That is, if the level of expenditures is K, the total expenditures on freight and truck freight are constrained to $P_rQ_r + P_tQ_t = K$, where Q_r and Q_t are the quantities of truck and rail freight, respectively, and P_r and P_t are the freight rate for rail and truck, respectively. Note that the slope of line ZZ' is equal to $-(P_r/P_t)$, which is the ratio of the price of rail freight to the price of truck freight. The equilibrium position (which minimizes total freight cost at P_r/P_t relative freight rates) is the tangency point at n. The volume of freight is Q_t and Q_r. Line MM' represents a different price ratio, which has a lower relative cost of rail freight.

Fuel composes part of the cost of providing both rail and freight service. The following cost functions are assumed to represent the cost of providing truck and rail services:

$$C_t = f(Q_t) + PaQ_t$$

and

$$C_f = f(Q_1) + PbQ_1$$

where Q_t is the quantity of truck freight in ton miles. Q_r is the quantity of rail freight in ton miles, P is the price of fuel, a is a constant that reflects fuel consumed per ton-mile of freight for trucks, b is a constant that reflects fuel consumed per ton-mile of freight for rail, and f(Q) represents the other nonfuel cost elements.

Trucks consume four times as much as rail per ton-mile of freight, therefore a = 4b. If fuel price increase the impact on cost will be

$$\frac{\partial D_t}{\partial P} + aQ_t$$

and

$$\frac{\partial C_r}{\partial P} + bQ_r$$

Since a = 4b, the change in cost per ton-mile on trucks is four times that of railroads. For example, if freight rates P_t and P_r are increased to fully reflect the increased fuel costs, rates increase to $P_t + dPa$ (for truck) and $P_r + dPb$ (for rail). This means that the slope of line ZZ′ will change so that the new price ratio will be similar to line mm′. The new equilibrium position j will be at a point on Q so that the quantity of rail freight will increase or the quantity of truck freight will decrease.

One possibility is that the Q may shift down towards the origin (for example Q^1). This would indicate that either the quantity of transportation services needed to support a given level of output had decreased or that the level of output (i.e., GNP) had decreased. In any case, the relative share of total transportation will be larger for rail (than for truck) after the fuel price increase.*

One additional observation should be made. First, it has been assumed that the price increase per BTU (of fuel) will be equal for rail and truck. If it is higher for rail than for truck, this will offset some rail fuel efficiency advantage. If it is greater for trucks (which seems most likely, due to the effect of market structure in petroleum) it will cause even a greater shift to rail.

Impacts on Consumers

The impact of a muffler retrofit program on consumers can be measured by the price increases that would result if rail freight rates are increased. Table 7-38 shows both the direct and indirect rail inputs for the commodities listed. The first column shows the cents of rail transportation per dollar of output for each commodity listed. For example, commodity 24, motor vehicles, requires 2.9¢ of rail transportation per dollar of sales. The 2.9¢ reflects all rail transportation inputs for raw materials, intermediate inputs, and the final product.

The second column shows the percent increase in selling price that would result from a 1-percent increase in rail freight rates. Note that this does not allow for a shift to other modes. If truck or water transport is used in place of part of the rail transport (because truck or water is cheaper after the rail price increase), the price increases will be smaller than those shown. The figures in the table, therefore, represent the maximum expected price increases resulting from a 1-percent rail freight rate increase.

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*This result depends upon Q being mathematically a convex set. The intuitive argument for convexity is that as rail is substituted for trucking transportation, the substitution becomes more difficult because in some applications rail service is quite inferior to truck. For a discussion of the theoretical points relating to this analysis, see C. E. Ferguson, *The Neoclassical Theory of Production and Distribution,* Cambridge University Press, 1969 or R. Frish, *Theory of Production,* Rand McNally & Co., 1965 [48].

TABLE 7-38
EFFECT OF A 1-PERCENT RAIL FREIGHT RATE INCREASE ON COMMODITY PRICES

Department of Transportation Sector	Rail Transportation (cents per dollar of selling price)	% Increase in Selling Price for a 1% increase in Freight Rates
1. Agriculture	2.0 ¢	.02
2. Iron ore mining	15.3	.153
3. Nonferrous mining	6.2	.062
4. Coal mining	20.8	.208
5. Miscellaneous mining	12.4	.124
6. Construction	2.2	.022
7. Ordnance	1.4	.014
8. Food and drugs	2.4	.024
9. Textiles and apparel	.9	.009
10. Lumber and products	7.5	.075
11. Furniture	2.3	.023
12. Paper and paper products	5.1	.051
13. Printing	1.4	.014
14. Chemicals	3.8	.038
15. Plastics, paints, and rubber	2.0	.020
16. Petroleum and products	1.0	.010
17. Stone, clay, glass products	3.8	.038
18. Iron and steel	3.9	.039
19. Nonferrous metals	2.7	.027
20. Fabricated metals	1.8	.018
21. Farm, construction machinery	2.7	.027
22. Industrial machinery	1.7	.017
23. Electrical machinery	1.1	.011
24. Motor vehicles	2.9	.029
25. Aircraft	.9	.009
26. Other transportation equipment	2.2	.022
27. Scientific, optical instruments	.6	.006
28. Communications	.3	.003
29. Utilities	2.7	.027
30. Services	.5	.005
31. Auto repairs	1.0	.010
32. Government enterprises	4.4	.044
33. Business travel, gifts	2.2	.022
34. Miscellaneous Manufacturing	2.7	.022
35. Scrap sales	14.5	.145

The freight rate increase necessary to offset the increased costs due to retrofit are shown in Table 7-39. This analysis assumes that there will be no reduction in freight volume as a result of these price increases. Given the small increases, this is a reasonable assumption. This analysis should not be construed as a recommendation for a freight increase, nor is it assumed that one would be granted.

TABLE 7-39
FREIGHT RATE NECESSARY TO OFFSET INCREASED COSTS DUE TO RETROFIT
(In Millions)

1973 freight revenue	$13,793.7
Retrofit cost (including fuel)	
year 1	49.23
year 2	54.78
Percent increase in rates necessary to recover all costs	
year 1	0.36%
year 2	0.39%
Recurring costs	$ 15.15
Percent increase in rates necessary to recover all recurring costs	0.11%

Section 8

ENVIRONMENTAL EFFECTS OF THE FINAL REGULATION

Beginning in 365 days, the regulation being promulgated will stop the noise emitted by railroad trains from increasing, and 4 years from the date of promulgation, will progessively reduce the noise presently emitted by railroad locomotives. As a result, the number of people currently subjected to annoying levels of railroad noise will be reduced.

A detailed analysis of both the number of people presently adversely impacted by railroad noise and the number who would potentially be relieved of such impact was presented in the Background Document for the proposed regulation. Since then studies utilizing different assumptions have been instituted by the Agency to attempt to more clearly assess the nature and extent of railroad noise and its possible abatement. Both analyses are presented in this section.

INITIAL ANALYSIS OF IMPACT RELATED TO ACOUSTICAL ENVIRONMENT

Case Studies of Railroad Lines

Ten cities with widely varying populations were selected to make detailed comparison of train traffic with population densities near railroad tracks and with the type of land use adjacent to tracks (see Table 8-1). Such comparisons provide a basis for determining how many people are exposed to railroad noise, how often they are exposed, and what activities they are engaged in at the time.

The schedules of trains moving over the railroad lines were determined from *The Official Guide of the Railways*, July 1973 [26], or from employee timetables. Estimates of speed maxima and minima were taken from employee timetables or obtained from railroad employees. Speeds for AMTRAK trains were not obtained. The period between 10:00 p.m. and 7:00 a.m. was designated as night, and the rest of each 24-hour period was designated as day. Table 8-2 summarizes the results of the 10 case studies.

Analysis of Train Noise Impact

There are three major noise sources that contribute to L_{dn} (see discussion of L_{dn} at the end of this section for a definition of L_{dn}) at point along and away from railroad tracks: locomotives, wheel/rail interaction, and horns or whistles.

TABLE 8-1
LAND USE NEAR RAILROAD LINES

City and State	Land Use Within 500 Ft of Track (Percent)			
	Residential	Business	Industrial & Other	Mileage Studied
Newton, Mass.	75	21	4	6
Boston, Mass.	59	9	32	7
Valparaiso, Ind.	43	8	49	9
St. Joseph, Mo.	42	13	45	26
Akron, Ohio	40	23	37	25
Somerville, Mass.	30	18	51	7
Michigan City, Ind.	29	15	56	17
Kalamazoo, Mich.	22	5	73	20
Altoona, Pa.	16	18	65	6
Ft. Lauderdale, Fla.	12	22	66	21
Lewiston, Maine	12	19	68	11
Denver, Colo.	12	3	85	51
Cheyenne, Wyo.	9	11	79	15
Cambridge, Mass.	8	24	68	9
Macon, Ga.	6	4	90	25
Average	28	14	58	Total 255

TABLE 8-2

TRAIN TRAFFIC AND COMMUNITY CHARACTERISTICS NEAR TYPICAL RAILROAD LINES

CITY & STATE	POPULATION	NUMBER OF FREIGHT TRAINS		MAXIMUM FREIGHT SPEED (mph)	NUMBER OF PASSENGER TRAINS		MAXIMUM PASSENGER SPEED (mph)	LAND USE (%)			NO. OF PEOPLE PER SQUARE MI. WITHIN 500 FT	MILEAGE STUDIED	
		DAY	NIGHT		DAY	NIGHT		RESIDENTIAL	BUSINESS	OTHER		LAND USE	POPULATION
Akron, Ohio	542,775	22	18	55	0	0	—	40	23	37	1,662	25	31
Altoona, Pa.	81,795	7	5	50	2	2	70	16	18	65	3,090	6	12
Boston, Mass.	961,071	0	8	40	0	0	—	59	9	32	20,660	7	7
Cheyenne, Wyo.	40,914	?	?	?	2	0	?	9	11	79	1,471	15	9
Columbus, Ind.	27,141	1	1	50	0	0	—	?	?	?	730	—	20
Denver, Colo.	1,047,311	24	10	60	4	0	?	12	3	85	3,027	51	26
Durham, N.C.	100,764	11	1	65	0	0	—	?	?	?	1,780	—	31
Michigan City, Ind.	39,369	5	2	50	2	0	50	29	15	56	608	17	43
Newton, Mass.	91,066	7	1	50	0	0	—	75	21	4	5,320	6	6
Valparaiso, Ind.	20,020	19	10	60	0	0	—	43	8	49	1,528	9	9

Figure 8-1 shows some L_{dn} profiles that were calculated by applying the prediction techniques to actual operations on a specific railroad line. The profiles shown in Figure 8-1 were calculated from the following data supplied by Penn Central:

10:00 p.m. and 7:00 a.m.
6 freight trains
each 14 loaded cars and 10 empty cars
40 mph
and
7:00 a.m. and 10:00 p.m.
36 passenger trains, each
40 mph

Passenger trains with eight cars correspond to the national average passenger loading of cars [25]. The curve for two cars is displayed to demonstrate the influence of the number of cars on the results.

Since there are no crossings along the branch picked for this study, no whistle noise was considered. In addition to the usual geometric attenuation, atmospheric absorption and ground surface attenuation were included in the calculation for Figure 8-1. (See the discussion of Excess Attenuation of Railroad Noise at the end of Section 8.)

Figure 8-2 shows L_{dn} profiles that were calculated for the average of all the train movements in the U.S. The profiles were calculated from the following data [25];

Urban Areas

4 freight trains by day, 2 by night, each 33 mph, 40 cars 3800 tons
2 passenger trains by day, 0 by night, each 36 mph, 6 cars

Nonurban Areas

3 freights by day, 2 by night, each 33 mph, 40 cars, 3800 tons
0 passenger trains

Figures 8-3 through 8-6 provide examples of the impact on the community of a program to equip locomotive exhausts with mufflers. Figure 8-3 shows that a muffler that provides 10 dBA of quieting will nearly halve the distance to which people are exposed to L_{dn} or 55 or more by train traffic on the Dorchester Branch of Penn Central (assuming that no other sources of locomotive noise produce levels comparable to exhaust noise levels). Figure 8-4 shows that there is a reduction of 24,000 people exposed to L_{dn} of 55 or more by train traffic on the 7.2-mile-long Dorchester Branch. Figure 8-5 is based on national average train traffic and also shows that a muffler that quiets locomotive exhaust noise by 10 dBA will more than halve the distance to which people are exposed to L_{dn} of 55 or more (assuming that no other sources of locomotive noise produce levels comparable to exhaust noise levels). Figure 8-6 shows that there is a corresponding 5.1 million reduction in the number of people exposed to L_{dn} of 55 or more based on national average train traffic.

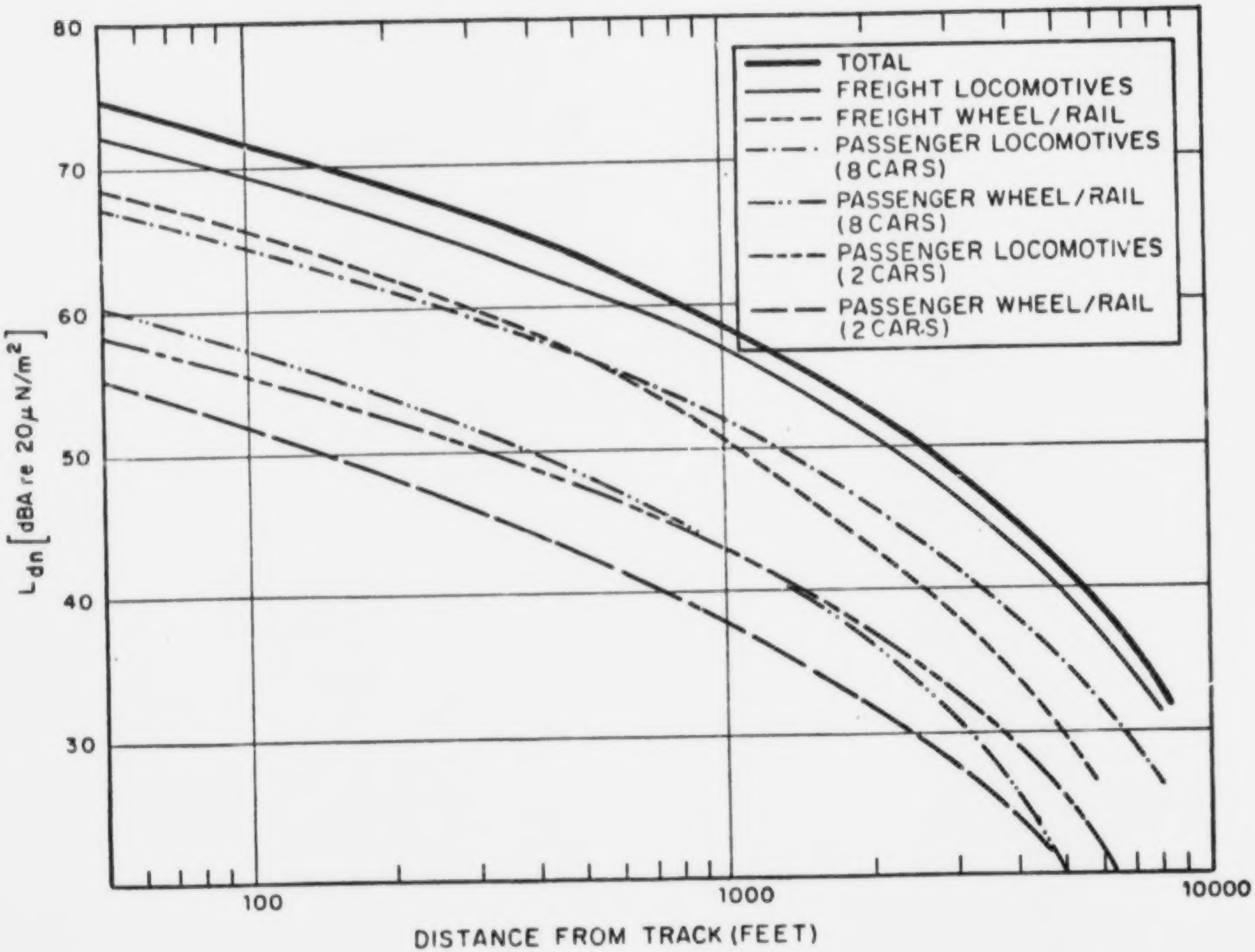

Figure 8-1. L_{dn} vs Distance From the Track for the Dorchester Branch of Penn Central

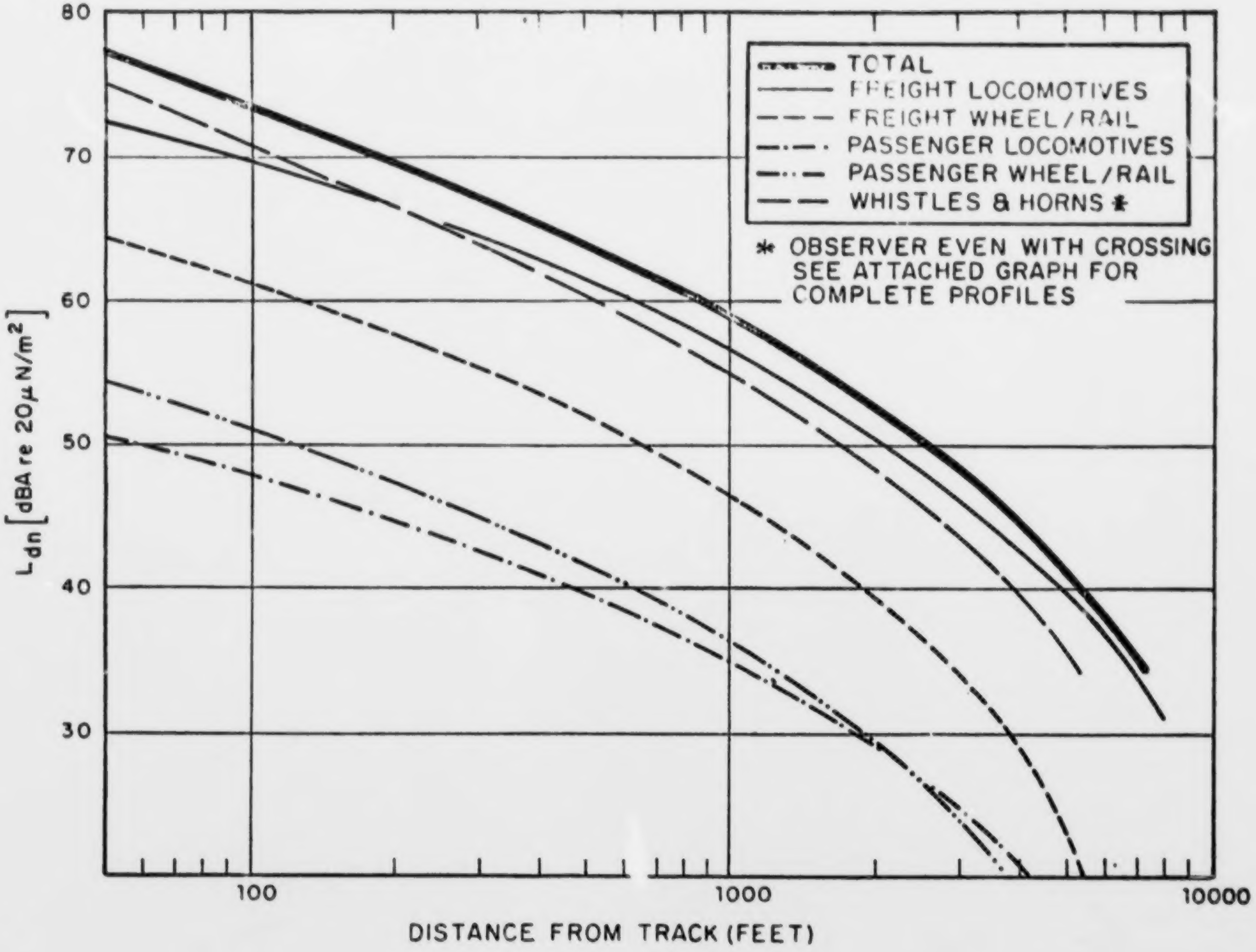

Figure 8-2. L_{dn} vs Distance From Track for National Average Train Traffic

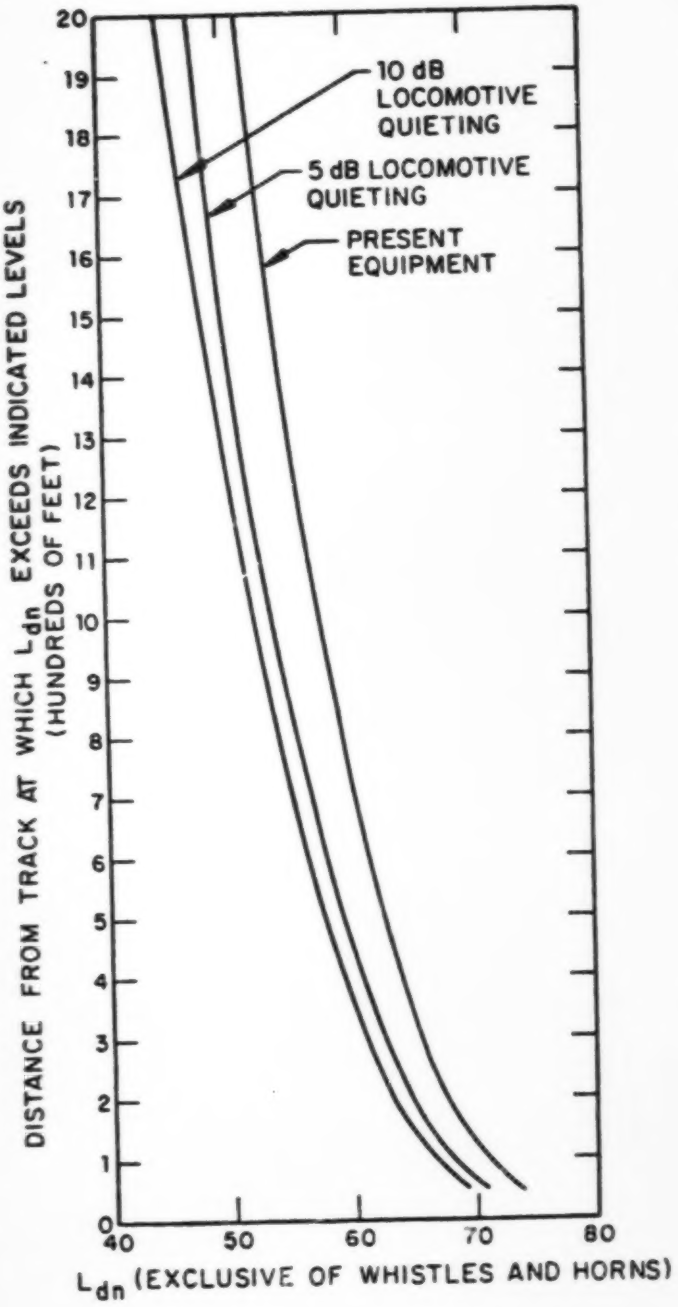

Figure 8-3. Distance From Track at Which Various L_{dn} Occurs Around the Dorchester Branch of the Penn Central

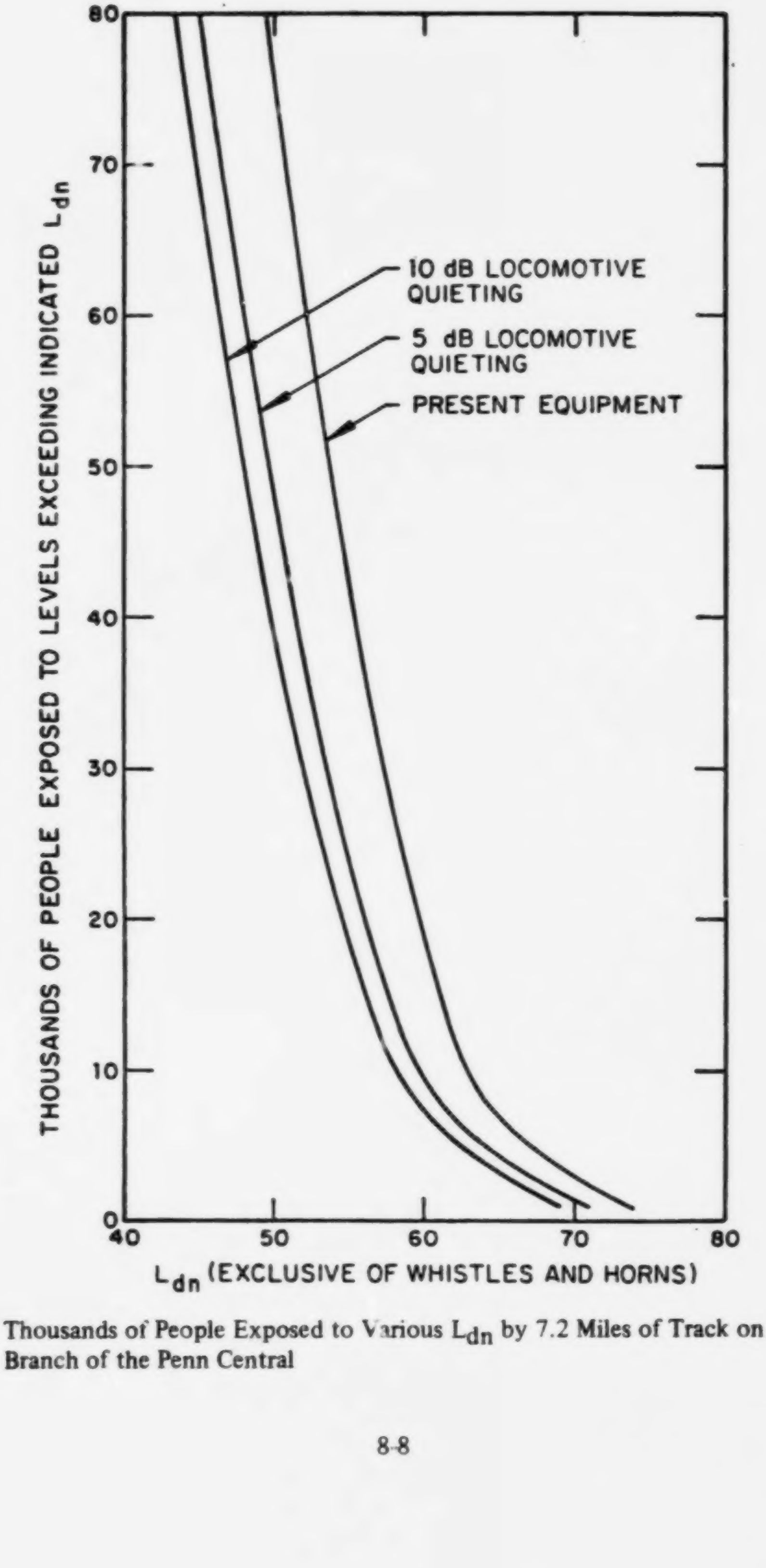

Figure 8-4. Thousands of People Exposed to Various L_{dn} by 7.2 Miles of Track on the Dorchester Branch of the Penn Central

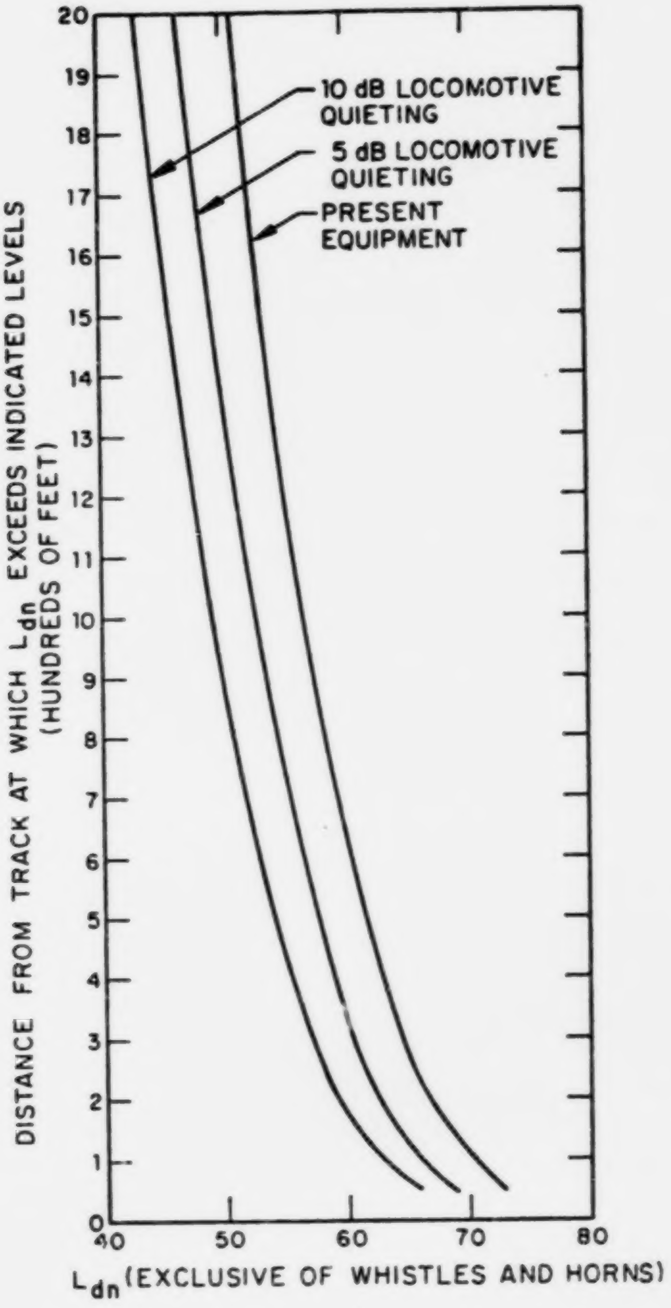

Figure 8-5. Distance From Track at Which Various L_{dn} Occur Due to National Average Train Traffic

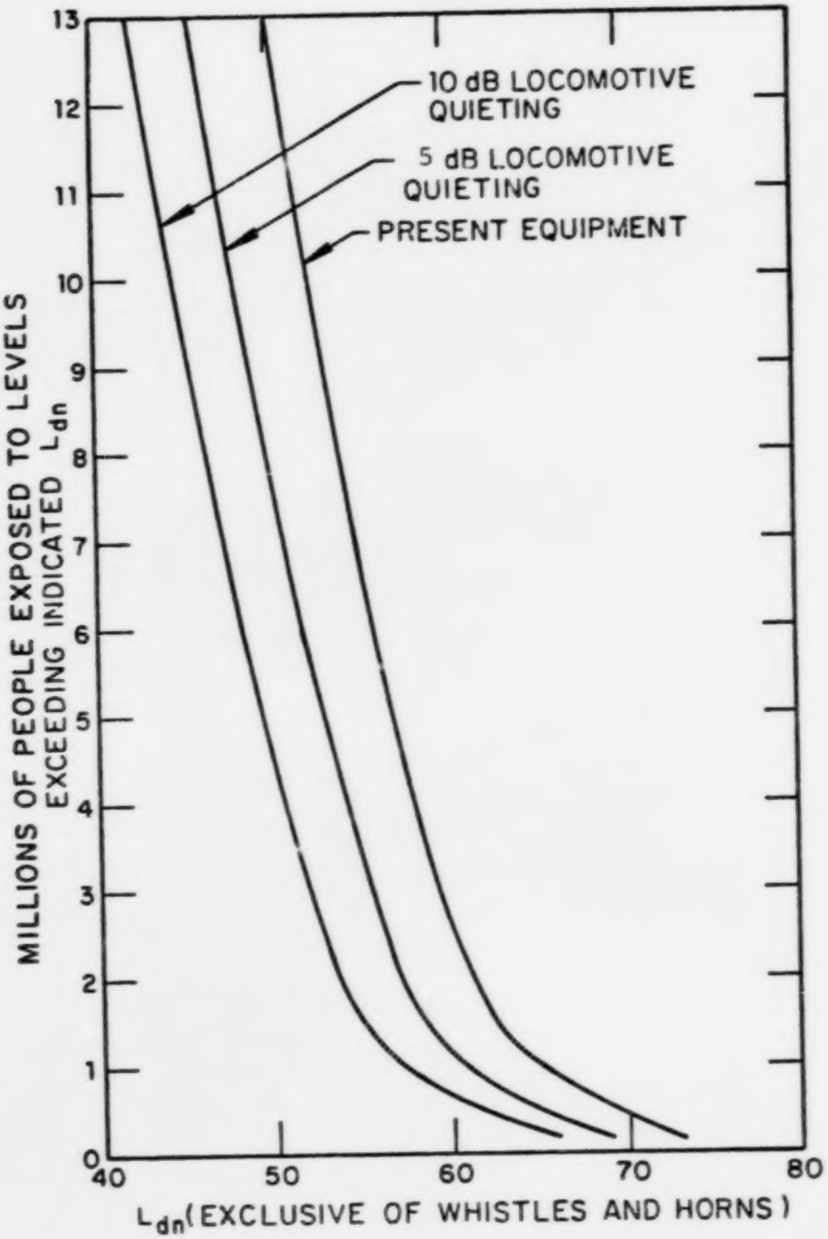

Figure 8-6. Millions of People Exposed to Various L_{dn} by National Average Train Traffic

Population densities used to construct Figures 8-3 and 8-6 were obtained from the U.S. Department of Commerce, Bureau of the Census. The census results show 28,098 people living within 1000 feet of the 7.2 miles of track comprising the Dorchester Branch of Penn Central. The population density in the first 500 ft next to the line was taken to be one-half of the density for the entire region, in keeping with national trends.

The figures for the number of people exposed to noise from national average train traffic were based on estimates of 30,000 miles of railroad rights-of-way in urban areas in the U.S. Urban areas are defined as the 40 Standard Metropolitan Statistical Areas (SMSAs) having average population densities in excess of 500 people per square mile and a total population greater than 250,000. The 40 SMSAs defined have a total land area of 58,200 square miles and a total population of 71,082,000, for an average population density of 1220 people per square mile. This figure must be modified, however, since there tends to be a concentration of industrial, commercial, and other nonresidential activities in the vicinity of rail lines. Land use and zoning maps indicate that the residential population density in the vicinity of a railroad line tends to be about 50 percent of the average density for the entire region.

REFINEMENTS ON INITIAL ANALYSIS OF IMPACT RELATED TO ACOUSTICAL ENVIRONMENT

This discussion contains an estimate of the number of people exposed by noise from railroad trains to noise levels of L_{dn} = 55 dB or more. This analysis differs from the analysis in the original Background Document; it contains a more rigorous estimate of the number of miles of track in urbanized areas and more conservative assumptions regarding the transmission of railroad noise into communities. This discussion also contains a recomputation of the exposure estimates given in the Background Document on the basis of improved data regarding numbers of locomotives and their average sound levels.

The number of people exposed depends on five factors:

1. The number of miles of railroad track in urban areas
2. The population density near railroads
3. The number of train operations per day
4. The noise level of the trains
5. The propagation of the train noise into the community.

Each factor will be addressed in turn.

Miles of Railroad Track

The original background document cited a Federal Highway Administration/Federal Railroad Administration (FHWA/FRA) report (1971) to the effect that there are 30,000 miles of railroad track in urbanized areas in the United States. The FHWA/FRA report cited no source for that figure, and direct inquiry with those agencies did not uncover a rationale for its derivation. In this analysis, therefore, an independent estimate shall be derived.

According to a survey of 106 cities [52], the percentage of the land in central cities presently devoted to railroad averages 1.7 percent in cities of 100,000 or more people and 2.4 percent in cities of 250,000 or more. The total land area of central cities having populations greater than 100,000 is approximately 9.84×10^3 sq mi [51]. If it is assumed that half of the land used by railroads is right-of-way (the remainder occupied by yards and terminals) and that the typical right-of-way is 100 ft wide, the following calculations results:

$$\tfrac{1}{2} \times .017 \times 9{,}840 \text{ mi}^2 \times \frac{5280 \text{ ft/mi}}{100 \text{ ft}} = 4416 \text{ miles.}$$

Therefore, it is estimated that there are approximately 4000 miles of right-of-way in central cities.

In another category of built-up areas, the urban fringe land area is 14,700 sq. mi. The percentage of that land used by railroads is not known; a figure of 1 percent, therefore, is assumed, of which half is devoted to rights-of-way. A calculation similar to the preceding one gives a figure of 3881 miles of right-of-way, which is rounded to 4000. The estimate, therefore, of the total mileage in urban areas, the sum of mileages in central cities and urban fringes, is approximately 8000 miles.

Population Densities

Hoyt [51] gives 58.6 million as the total population of central cities having populations of 100,000 or more. Dividing that figure by the total area of 9.84×10^3 sq mi. (see preceding discussion) gives an average density of 5.9×10^3 people per sq. mi. Census maps of land in the vicinity of central-city railroad lines indicate that the population density near rail lines is slightly less than half that of the local average [8]. One reason is probably the concentration of industrial and commercial property near rights-of-way. It is therefore estimated that the population density near central city rail lines is approximately 2500 people per sq mi.

The population of the urban fringe is roughly 48 million. Dividing by the area (14,700 sq mi.) gives an average density of 3300 people per sq mi. Statistics on the density near railroad tracks are not available. It is reasonable to assume, however, that the ratio of the density near tracks to the average density is less than one, but greater than the ratio for central cities because of the prevailing lower concentrations of industry and commerce in urban fringes. It is therefore estimated that the near-tracks population density in urban fringes is 2500 people per sq mi., or the same density as was derived for the central cities.

Traffic Volume in Urban Areas

Statistics on the frequency of train movements along urban rights-of-way may not exist. However, these statistics can be estimated on the basis of a study of train movements through highway grade crossings in urban areas [45]. If it is assumed that the traffic observed at grade crossings is a representative sample of traffic along the rail network as a whole, then the distribution of traffic at grade crossings can be used to determine the statistics in which we are interested. The distribution observed in Reference is given in Table 8-3.

The mean of this distribution is approximately 8 trains per day.

As a check on this figure, the average traffic on a random segment of railroad line can be estimated from a knowledge of national train traffic totals. Tables 8-4 and 8-5 show the numbers of miles of right-of-way, train-miles per year, and road locomotive-miles per year, as derived from ICC statistics for 1971 (the latest year for which detailed data is available). From these statistics,

TABLE 8-3

DISTRIBUTION OF URBAN GRADE CROSSINGS BY VOLUME OF TRAIN TRAFFIC

Trains per Day	Percent of Grade Crossings
0 to 2	40
3 to 5	18
6 to 10	20
11 to 20	13
21 to 40	6
over 40	3

TABLE 8-4

COMPUTATION OF NATIONAL AVERAGE DIRECT-POWERED TRAIN TRAFFIC

Train Type	Miles of Right-of-Way (a)	Train-miles per Year (b)	Average Trains Per Day Per Segment of Right-of-Way (b ÷ a ÷ 365)
Freight	210×10^3	425×10^6	5.5
Passenger	40×10^3	42×10^6	2.9

[1] Source: ICC, 1971.

TABLE 8-5
AVERAGE TRAIN CHARACTERISTICS[1]

Train Type	Train-miles per Year[2] (a)	Road Locomotive Miles per Year[2] (b)	Locomotives per Train (b ÷ a)	Car-miles per Year[2] (c)	Cars per Train (c ÷ a)
Freight	430×10^6	1280×10^6	3.0	29620×10^6	68.8
Passenger	6.95×10^6	100×10^6	1.4	389×10^6	5.6

[1] Figures include all forms of motive power.

[2] Source: ICC, 1971.

the average number of trains per day over a segment of right-of-way and the number of locomotives per train can be computed. These are displayed in the third column of Table 8-4 and 8-5, respectively, for freight and passenger traffic. If it is assumed that right-of-way in cities is used for both freight and passengers, then it can be seen from the third column that the total average train traffic (freight plus passenger) is 8.4 trains per day. This total agrees with the previous estimate. Assuming that freight trains are distributed randomly in time, it is estimated that at the average location four freight and one passenger trains pass during the day (7 a.m. to 10 p.m.) and two freight and one passenger trains pass at night.

Average locomotives per train and cars per train are similarly developed in Table 8-5. The last characteristic, train speed, is obtained by inspection of railroad employee timetables for the Northeastern United States. These timetables show 33 mph as the average maximum allowed speed for freight trains and 36 mph for passenger.

People Exposed

To determine the number of people exposed to various levels of L_{dn}, it is necessary to determine

- The energy radiated into the community by a single train passing by.
- The equivalent energy radiated by the national average train traffic.
- How the intensity of the sound varies with distance from the track.

The Single-Event Noise Exposure Level (SENEL) of a group of n locomotives passing by a fixed observer at perpendicular distance r_o from a track is given by the formula:

$$(\mathrm{SENEL})_L = L_L + 10 \log \left(\frac{\pi}{2} \frac{r_o}{V}\right) + 10 \log n , \qquad (8\text{-}1)$$

where the subscript L denotes locomotive, L_L is the level measured by a stationary observer at distance r_o from the locomotive, and V is the locomotive speed in ft per sec.*

The value of L_L computed by averaging the levels reported in Table 4-2 of the original Background Document (U.S.E.P.A., 1974) with the levels shown in Table 4-1, Appendix J, p. J16 of this document, is approximately 90 dBA. For a freight train with three locomotives traveling at 33 mph,

$$\begin{aligned} \mathrm{SENEL}_L &= 90 \text{ dBA} + 10 \log \left(\frac{\pi}{2} \frac{100 \text{ ft}}{48 \text{ ft/sec}}\right) + 5 \text{ dB} \qquad (8\text{-}2) \\ &= 100.1 \text{ dBA at } 100 \text{ ft}. \end{aligned}$$

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*A theoretical derivation of this expression is given in Rudd and Blackman [61]. According to that derivation, the second term should be $10 \log (\pi r./V)$. Experience with actual passby measurements indicates that $10 \log (\pi r/2V)$ gives a better approximation to the data.

The energy radiated by the cars in a train as measured at 100 ft is expressed as

$$\mathrm{SENEL}_C = 72 + 30 \log \frac{V}{20} + 10 \log t \,, \tag{8-3}$$

where V is train speed in miles per hour and t is the passby time in seconds (Source: Bender *et al.*, 1974).

For a train speed of 33 mph and a passby time of 73 sec (70 cars × 50 ft/car ÷ 48 ft/sec),

$$\mathrm{SENEL}_T = \log \left[\log^{-1} \left(\frac{\mathrm{SENEL}_L}{10} \right) + \log^{-1} \left(\frac{\mathrm{SENEL}_C}{10} \right) \right] \tag{8-4}$$

$$= 101.9 \text{ dBA at 100 ft.}$$

In the preceding expression, T denotes total.

To compute the equivalent day-night energy level, the SENELs for all events are summed and divide by 24 hours, while the nighttime events are weighted by a factor of 10. Table 8-4 shows that approximately six trains move over the average segment of track each day. (Passenger trains are typically 10 to 20 dB quieter than freight trains and so are excluded from the exposure estimate (see figure IX.15 of Reference 8.) Assuming that the train movements are distributed evenly through the day, this traffic breaks down into two night and four day events. The equivalent number of movements is therefore 2 × 10 + 4 = 24. The L_{dn} at 100 ft from a segment of average track is, therefore,

$$\begin{aligned} L_{dn} &= \mathrm{SENEL}_T + 10 \log 24 - 10 \log (3600 \text{ sec/hr} \times 24 \text{ hrs}) \\ &= 66.3 \text{ dBA.} \end{aligned} \tag{8-5}$$

The model for train noise propagation into communities is based on the model developed for urban highway noise by Kugler, Commins, and Galloway [72]. The theory on which that model is based shows the noise falloff with distance from the track (or highway) to be 4.5 dB per doubling of distance. In addition, there will be another 4.5 dB of attenuation caused by the shielding effects of the first row of buildings next to the track. This attenuation behavior is approximated by using a straight line falling off at a rate of 6 dB per doubling of distance. This approximation is reasonably accurate (given the uncertainty of the precise location of the shielding buildings) out to about 700 ft, which is beyond the limit of the range of interest. With this propagation model and the L_{dn} level at 100 ft (called L_{100}), the range, r, to any L_{dn} level can be computed using the expression

$$r = 100 \text{ ft} \times 10^{(L_{100} - L_{dn})/20}. \tag{8-6}$$

Using Equation 8-6, the figure for L_{dn} at 100 ft as developed previously, a population density of 2500 per sq. mi., and the figure of 8000 miles of urban track, the number of square miles is estimated and, hence, the number of people exposed to various levels of L_{dn}. These are summarized in Table 8-6, which shows the distribution of people by L_{dn} interval, and Table 8-7, which shows the cumulative distribution.

The number of people eliminated from each exposure level by a muffler retrofit program may be computed. First, note that the proposed standard would require locomotives to radiate less than 87 dBA at 100 ft. It is therefore assumed that all locomotives now in excess of the standard will be quieted to a level of 86 dBA. Using Equation 8-2,

$$\text{SENEL}_L = 96.1 \text{ dBA at 100 ft.}$$

is computed for the quieted condition.

The noise radiated from the rest of the train will remain unchanged, so, using Equation 8-4,

$$\text{SENEL}_T = 99.7 \text{ dBA at 100 ft.}$$

This is 2.2 dBA less than the unquieted SENEL_T (see Equation 8-4). The overall reduction in L_{dn} will therefore amount to 2.2 dBA, which gives a figure of

$$L_{dn} = 64.1.$$

The distribution of people by L_{dn} interval for the quieted case is shown in Table 8-8; the cumulative distribution is shown in Table 8-7.

The exposure estimates given in Table 8-7 are more conservative than those given in the original Background Document [8] in that they assume a degree of shielding from nearby structures. In addition, the estimates provided in the Background Document assume that each train is hauled by four locomotives, each having a noise level of 92 dBA at 100 ft. We have determined from current statistics that a more reasonable assumption is 3 locomotives, each having a noise level of 90 dBA.

If the propagation loss model used in the Background Document (e.g., 4.5 dB per double distance were used, plus atmospheric attenuation) while correcting the overall noise level by 3 dB to account for the improved estimates of the number and noise levels of locomotives, the net effect would be to reduce the overall L_{dn}'s as shown in the original Background Document [8] by 3 dB at all distances. The Background Document's estimate of 7 million people exposed to $L_{dn} = 55$ or over would be reduced to 5 million. The net benefit of a 4-dB locomotive noise reduction would be a 2-million-person reduction in the number of people exposed to L_{dn} levels over 55 dB.

In view of the present uncertainty as to the proper attenuation model to use, the computation shown in Table 8-7 is regarded as a conservative estimate of railroad noise exposure and the revised original Background Document [8] computation as an upper-bound estimate.

The overall impact of railroad noise may be judged by computing the Equivalent Noise Impact (ENI), which shows, from the figures in the last column of Table 3-6, the equivalent number of people exposed to levels 20 dB above the criterion level. In the case of residential areas, the criterion level is $L_{dn} = 55$ dBA [66]. To make this computation, each segment, i, of

TABLE 8-6
PRESENT DISTRIBUTION OF PEOPLE BY L_{dn} INTERVAL

L_{dn} Interval	Distances of Strip Boundaries from Track (ft)	Width of Strip (ft)	Aggregated Area of Strips in U.S. (sq. mi.)	People Within Strip (million)
65–70 dBA	65–116	51	155	0.387
60–54	116-207	91	276	0.690
55–60	207-367	160	485	1.213

TABLE 8-7
PRESENT AND PROJECTED POPULATIONS EXPOSED TO VARIOUS LEVELS OF L_{dn}
(Cumulative)

L_{dn}	Millions of People Exposed to Given L_{dn} or Greater	
	Present	4 dB Locomotive Noise Reduction
55 dBA	2.29	1.77
60	1.80	0.83
65	0.39	0.30
70	–	–

TABLE 8-8

DISTRIBUTION OF PEOPLE BY L_{dn} INTERVAL ASSUMING MUFFLER RETROFIT

L_{dn} Interval	Distances of Strip Boundaries from Track (ft)	Width of Strip (ft)	Aggregated Area of Strips in U.S. (sq. mi.)	People Within Strip (million)
65–70 dBA	51–90	39	118	0.295
60–65	90–160	70	212	0.530
55–60	160–285	125	379	0.948

the exposed population is weighted by its Fractional Impact (FI_i), as given by the following expression:*

$$FI_i = 0.05\,(L_i - 55) \text{ for } L_i > 55 \text{ dBA}$$

$$FI_i = 0 \qquad \text{for } L_i \leq 55 \text{ dBA}$$

The ENI is then computed using the formula

$$ENI = \sum_i FI_i \cdot P_i \ ,$$

where P_i is the population in the i^{th} exposure interval.

Applying these expressions to the population figures shown in Tables 8-6 and 8-8 gives the results shown in Table 8-9. A muffler retrofit program will reduce the Equivalent Noise Impact by 151,000 people.

Impact Related to Land

These regulations will have no adverse effects relative to land.

Impact Related to Water

These regulations will have no effect on water quality or supply.

Impact Related to Air

The use of more efficient exhaust muffling systems can cause a change in the back pressure to the engine and may result in a change in the exhaust emissions level. The data, at present, are

TABLE 8-9

EQUIVALENT NOISE IMPACT FOR PRESENT AND QUIETED LOCOMOTIVE POPULATIONS

L_{dn} Interval	Population P_i (millions)	Fractional Impact F_i	FI_i X P_i (millions)
Current Noise Impact			
65-70 dBA	0.387	0.625	0.242
60-65	0.690	0.375	0.259
55-60	1.213	0.125	0.152
			Total ENI = 0.653
Projected Noise Impact with Muffler Retrofit			
65-70 dBA	0.295	0.625	0.184
60-65	0.530	0.375	0.199
55-60	0.948	0.125	0.119
			Total ENI = 0.502

insufficient to make other than a general statement concerning the directions the various emission levels take when a different back pressure is applied, since the behavior of the various engines and exhaust emission control systems vary widely. However, internal combustion engine exhaust emissions are affected by changes in exhaust system back pressure, and they must be considered. It is important to note, however, that motor carrier exhaust emissions are higher than rail carrier exhaust emissions per ton mile of goods transported, indicating that, in the overall balance, rail carriers are already more efficient than motor carriers from an exhaust emission standpoint.

It must also be noted that promulgating stricter rail carrier noise regulations at this time may inadvertently divert cargo traffic from the rails toward motor carriers due to difficulties in compliance with regulations, thereby causing an increase in total exhaust emissions to the atmosphere as well as increasing noise emissions. Based on the analysis presented, problems such as this are not expected to arise as a result of the proposed regulation.

DAY NIGHT EQUIVALENT NOISE LEVEL (L_{dn})

L_{dn} is a modified energy-equivalent sound level. The energy-equivalent sound level L_{eq} is the level of the continuous sound associated with an amount of energy equal to the sum of the energies of a collection of discontinuous sounds. L_{eq} is defined by

$$L_{eq} = 10 \log \frac{1}{t_2 - t_1} \int_{t_1}^{t^2} 10^{NL/10} \, dt$$

where NL is the instantaneous overall noise level in dB(A) at time t, and the time period of interest is from time t_1 to time t_2. L_{dn} is determined precisely like L_{eq}, except that all noise levels NL measured at night (between 10:00 p.m. and 7:00 a.m.) are increased by 10 dB(A) before being entered into the above equation.

EXCESS ATTENUATION OF RAILROAD NOISE

Many mechanisms cause attentuation of sound beyond that caused by geometric spreading, including molecular absorption in the air, precipitation, barriers, ground cover, wind, and temperature and humidity gradients. The attenuation variest with location, time of day, and season of the year. To account for the attenuation produced by these highly variable sources, it is necessary to compile detailed records of wind, temperature, humidity, precipitation, and even cloud cover on a statistical or probabilistic basis. The following discussion is directed at a base case that includes two reliable sources of excess attenuation: atmospheric molecular absorption and attenuation associated with variations in the physical characteristics of the atmosphere near the ground. Both attenuations vary with frequency. The attenuation factors were evaluated for reference conditions of 50°F and 50 percent relative humidity.

Figure 8-7 shows how atmospheric molecular absorption and variations of atmospheric characteristics near the ground change the shape of the locomotive noise spectrum. The high frequencies become less important as the sound travels outward from the source. The attenuation of the overall sound level (logarithmically summed octaveband sound levels) was found to be about 2 dB per thousand feet out to 400 ft. That value was used to calculate the propagation of locomotive noise described in this report. The value for the effective overall attenuation coefficient for locomotive noise is about the same for throttle position 8 and throttle position 1.

Figure 8-8 shows how the frequency-dependent attenuations change the shape of the spectrum of wheel/rail noise. Notice that here, too, the high frequencies become less important as the sound travels outward from the source. The attenuation of the overall sound level (logarithmically summed octaveband sound levels) was about 3 dB per thousand feet out to 3000 ft. That value was used to calculate the propagation of locomotive noise described in this Background Document.

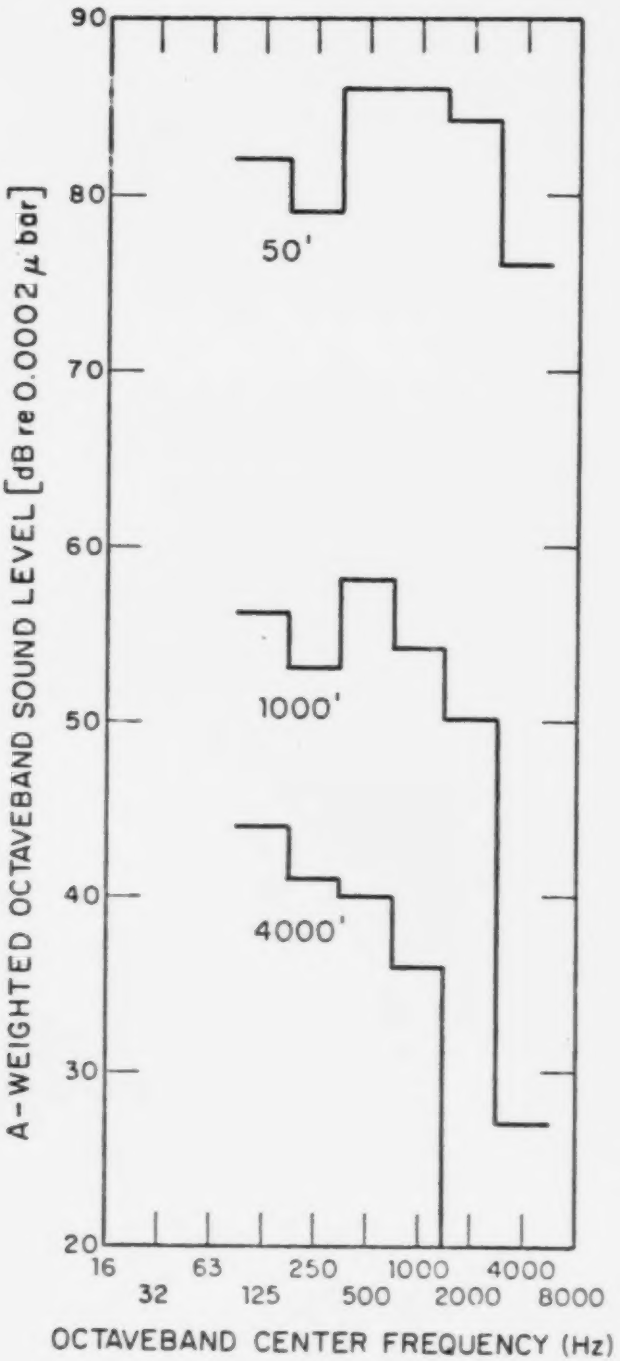

Figure 8-7. Influence of Frequency-Dependent Attenuations of Locomotive Noise Spectrum

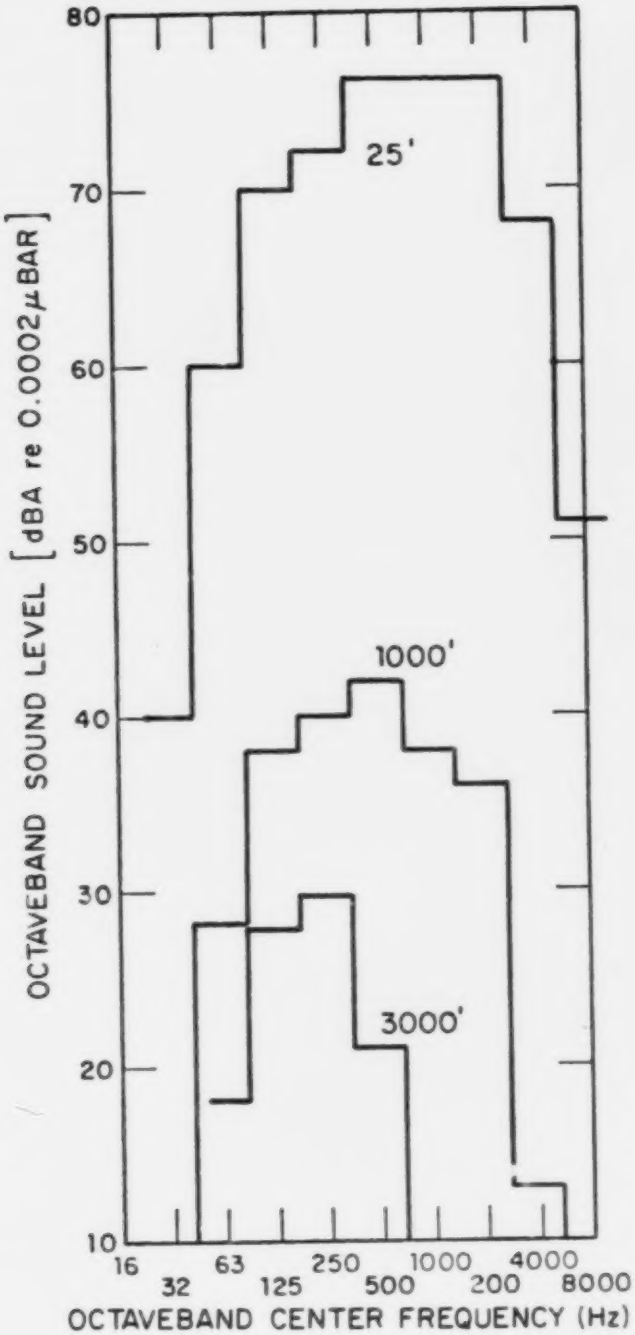

Figure 8-8. Influence of Frequency-Dependent Attenuations of Wheel/Rail Noise, Train No. 6, Region 2

Section 9

ECONOMIC EFFECTS OF THE FINAL REGULATION

The costs incurred in the muffling of newly manufactured locomotives may be more readily identified than in the case of locomotive retrofit. The following discussion identifies the major cost areas involved in the muffling of newly manufactured locomotives, including initial costs as well as increased operating and maintenance costs incurred.

EQUIVALENT ANNUAL INCREASED LOCOMOTIVE MANUFACTURING COSTS ATTRIBUTABLE TO MUFFLER INTRODUCTION

Type	No of Locomotives [8]	Unit Incremental Manufacturing Cost [8]	Total Cost (Millions of Dollars)
GM Road	843	\$3025-\$3630	\$2.55-\$3.06
GM Switcher	146	\$ 242-\$ 605	\$0.04-\$0.09
GE Road	100	\$1815	\$0.18
	1089		\$2.77-\$3.33

Total Annual Manufacturing Cost = \$2,770,000-\$3,330,000

Total Annual Manufacturing Costs Expressed as a Capital Investment Depreciated Over 25 Years.

$$\frac{\$2,770,000}{25} = \$110,800 \qquad \frac{\$3,330,000}{25} = \$133,200$$

Annual Incremental Manufacturing Costs = \$110,800-\$133,200

Equivalent Annual Increased Manufacturing Costs (over 25 years, i = 12%)

$$= 6.77 \times \$110,800 + \$110,800 = \$\ 860,900$$

$$= 6.77 \times \$133,200 + \$133,200 = \$1,034,900$$

Equivalent Annual Increased Manufacturing Costs = \$860,900-\$1,034,900

- *The Average Cost Increase Per Locomotive Will Be*

  $$\frac{\$2,770,000}{1089 \text{ locos.}} = \$2544/\text{locomotive} \qquad \frac{\$3,330,000}{1089 \text{ locos.}} = \$3058/\text{locomotive}$$

  \$2550-\$3060 per locomotive average cost increase.

- *Expressed As a Percentage of New Locomotive Costs*

$\frac{\$\ 2{,}550}{\$337{,}000} = 0.75\%$ $\frac{\$\ 3{,}060}{\$337{,}000} = 0.91\%$

where $337,000 equals the 1975 average price of a new locomotive without a muffler [72].

The addition of mufflers to newly manufactured locomotives should cause an approximately 0.75 to 0.91 percent unit price increase.

EQUIVALENT ANNUAL INCREASED FUEL COSTS ATTRIBUTABLE TO MUFFLER INTRODUCTION ON NEWLY MANUFACTURED LOCOMOTIVES (OVER AN ESTIMATED 25-YEAR FLEET REPLACEMENT PERIOD)

- *Population of owned locomotives [68], assumed constant = 27,117.*
- *Average No. of new locomotives manufactured annually = 1089.*
- *Annual Fuel Cost Increase (Based on 1% Increased Consumption):*

After 25-yr. fleet replacement period* = $11,900,000.

To determine an annual increased fuel cost for the initial 25 year period during which fuel costs attributable to muffled locomotives increase in a gradient fashion as the number of muffled locomotives similarly increases, the equivalent annual cost has been calculated:

First Year Increased Fuel Cost:

$$= \frac{1089 \text{ new locomotive's} \times \$11{,}900{,}000}{27{,}117 \text{ fleet locomotives}}$$

$$= \$480{,}000$$

Equivalent Annual Increased Fuel Cost (over 25 yrs., i = 12%):

$$= 6.77 \times \$480{,}000 + \$480{,}000$$

$$= \$3{,}730{,}000$$

Equivalent Annual Increased Fuel Cost = $3,730,000.

MUFFLER REPLACEMENT COSTS

It is anticipated that mufflers can be designed to last the life of the locomotive and will require only highly infrequent replacement. Mufflers may be constructed of heat resistant, anti-corrosive alloys that will extend their useful lives. Also an important consideration is the fact that the muffler will be located within the carbody of the locomotive and will be sheltered from the harmful effects of exposure to the elements. Further, industrial mufflers have been designed to have useful lives of more than 20 years and it is expected that locomotive mufflers may be designed for similarly long life spans. Accordingly, it is expected that muffler replacement costs will be negligible.

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*$11,900,000 annual fuel cost increase computed by updating AAR's (1% or 40,000,000 gal./year) increased fuel costs estimate of $11,600,000 at 1974 prices (29 cents/gal.) to 1975 price of (30 cents/gal.).

SUMMATION OF THE MAJOR COSTS INCURRED THROUGH THE ADDITION OF MUFFLERS TO NEWLY MANUFACTURED LOCOMOTIVES:

- Annual incremental locomotive manufacturing costs attributed to muffler introduction:

  $860,900-$1,034,900

- Equivalent Annual increased fuel costs (over 25 yrs., i = 12%):

  $3,730,000

- Total Cost: $4,590,900-$4,764,900

- Costs to be incurred by bankrupt and marginal railroads:

  Seven bankrupt railroads may absorb approximately 22 percent of the cost for the industry.*

  Eleven marginal railroads may absorb approximately 6 percent of the cost for the industry.

NOTE: (1) All dollar amounts used in the preceding discussion have been converted from 1973 and 1974 dollars to 1975 dollars, using the Bureau of Labor Statistic's "Wholesale Prices and Price Indexes, WPI Code 24-4, Railraod Equipment", 1975.

(2) Annual equivalent costs are the equal annual annuity payments made on a hypothetical loan borrowed by the user of a product to pay for the additional annual operating, maintenance, and capital expenditures incurred over the life of the product due to the application of noise abatement technology. The principal of this hypothetical loan is equal to the total present value of these initial and future expenditures.

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*Percentage estimates based on present locomotive ownership, assuming that these railroads will buy new locomotives in numbers proportional to the size of their present fleets.

SECTION 10

INDEX OF PUBLIC COMMENTS ON THE INTERSTATE RAIL CARRIER NOISE EMISSION REGULATIONS

DOCKET NO. PERSON OR ORGANIZATION	COMMENT	PAGE NO. OF REPLY BY EPA IN DOCKET ANALYSIS
R001 Mr. B. Leath	1. Commented that railroad acoustic warning signals are ineffective due to often load noise levels that exist in motor vehicle interiors	7
	2. Suggested that roadway drop gates equipped with flasher units provide adequate visual warning without acoustic signals	
R002 State of New York, Department of Environmental Conservation, Albany	1. Suggested that the term "retarder" be eliminated from Section 201.1	2
	2. Suggested that railroad warning devices be regulated	4
	3. Suggested test equipment and requested the specification of error tolerances within the measurement procedures	45
	4. Commented that the 100 ft. measuring distance in the standards is too far	46
R004 Shell Oil Company	1. Suggested that the Federal standards should not apply to private-owned cars	28
R005 ADM Company	1. Commented that since a track standard was not included in the regulation, quiet railcars might be penalized for wheel/rail noise caused by faulty track	15
	2. Commented that the EPA rail car noise standards would require greater maintenance than that prescribed by the FRA (1974) railroad freight car safety standards already in effect	

DOCKET NO. PERSON OR ORGANIZATION	COMMENT	PAGE NO. OF REPLY BY EPA IN DOCKET ANALYSIS
R009 Mr. R. Harnden	1. Commented that the proposed regulations would have a substantial adverse economic impact upon bankrupt and marginal railroads	35
	2. Commented that adequate information as to the number of people impacted by railroad noise or benefited by the regulation was not provided	40
	3. Suggested that the regulation of railroad equipment in rural areas is not called for	40
R010 Mr. E. Schmidt	1. Commented that adequate information as to the number of people impacted by railroad noise or benefited by the regulation was not provided	40
	2. Suggested that the regulation of railroad equipment in rural areas is not called for	40
R011 U.S. Department of Transportation	1. Suggested that the terms "retarder" and "sound pressure level" be eliminated from Section 201.1	2
	2. Questioned why EPA chose to regulate only certain railroad equipment and not all railroad facilities and equipment at this time	2
	3. Suggested that retarder noise emissions be regulated	10
	4. Suggested that a regulation be promulgated to protect railroad workmen from retarder noise	12
	5. Suggested the inclusion of noise standards for refrigerator cars in the regulation	16
	6. Suggested that refrigerator car owners' ability to pay for mufflers be considered apart from the economic position of the railroads	18
	7. Questioned the acoustical acceptability of the typical load cell test site	24

DOCKET NO. PERSON OR ORGANIZATION	COMMENT	PAGE NO. OF REPLY BY EPA IN DOCKET ANALYSIS
R011 DOT (cont.)	8. Questioned the validity of the self loading test	25
	9. Commented that local enforcement of stationary standards could result in obstruction of routine railroad operation	25
	10. Suggested a moving locomotive standard as a substitute for a stationary standard and that EPA's definition of wayside surface conditions be improved	26
	11. Commented that it is appropriate to limit any rail car regulation to curves of 2 degrees or more	27
	12. Commented that the 270-day standards provide a disincentive to rebuild old locomotives into compliance or to specify new locomotives be delivered with the mufflers needed to comply	28
	13. Suggested $153 million for retrofit as opposed to original EPA estimates of $80-$100 million	34
	14. Suggested types of test equipment that should be utilized	45
	15. Suggested certain sound measurement parameters in the regulation	45
	16. Requested more than 270 days to develop compliance regulations	46
	17. Suggested that EPA propose property line standards on railroad noise	50
R012 Illinois railroad Association (IRA)	1. Questioned why EPA chose to regulate only certain railroad equipment and not all railroad facilities and equipment at this time	2
	2. Commented that mufflers may cause excessive backpressure when applied to locomotives	36
	3. Commented that local governments do not have the ability to determine the technical feasibility and cost of compliance of noise regulations	43

DOCKET NO. PERSON OR ORGANIZATION	COMMENT	PAGE NO. OF REPLY BY EPA IN DOCKET ANALYSIS
R012 (cont.)	4. Commented that local governments could make the federal regulation meaningless by exercise of their non-preempted regulatory authority	49
R013 Association of American Railroads (AAR)	1. Questioned why EPA chose to regulate only certain railroad equipment and not all railroad racilities and equipment at this time	2
	2. Suggested that EPA should prescribe noise standards for area-type sources such as yards	8
	3. Suggested that EPA establish noise limits applicable to noise from special purpose equipment	13
	4. Commented that a muffler which meets the proposed full throttle standard is not likely to meet the idle requirement too	20
	5. Commented that EPA understimated retrofit-muffler introduction costs	29
	6. Commented that the proposed regulations may have substantial adverse economic impact upon bankrupt railroads	35
	7. Commented that mufflers may cause excessive backpressure when applied to locomotives and warned of increased chemical and particulate air emissions	36
	8. Commented that carbon collection in mufflers presents a potential fire hazard	37
	9. Commented that increased railroad rates to cover compliance costs may divert traffic to more fuel intensive and polluting modes	37
	10. Commented that the application of mufflers will result in decreased reliability of locomotives	38

DOCKET NO. PERSON OR ORGANIZATION	COMMENT	PAGE NO. OF REPLY BY EPA IN DOCKET ANALYSIS
R013 (cont.) (AAR)	11. Commented that muffler manufacturers would have difficulty in designing mufflers for particular engines unless they knew all the parameters of the engines involved	39
	12. Suggested information be given as to whether people were adversely affected by railroad noise from a health and welfare standpoint initially	40
	13. Commented that, as a matter of statutory interpretation, EPA must regulate all railroad noise sources according the noise control act of 1972	42
	14. Commented that the setting of federal emission standards for locomotives and railcars should preempt every effort to control noise from that same equipment by local authorities	43
R015 Department of Environmental Quality, Portland, Oregon	1. Suggested that railroad warning devices be regulated	4
	2. Commented that acoustic warning devices are not needed around railroad yards	6
R016 Fruit Growers Express Company, et. al	1. Questioned why EPA chose to regulate only certain railroad equipment and not all railroad facilities and equipment at this time	2
	2. Suggested the inclusion of noise standards for refrigerator cars in the regulation	16
	3. Requested an extension of the period of time prior to promulgation of the final regulation so that refrigerator car noise emissions could be studies in relation to wheel/rail noise	18

DOCKET NO. PERSON OR ORGANIZATION	COMMENT	PAGE NO. OF REPLY BY EPA IN DOCKET ANALYSIS
R017 Salt River Project, Phoenix, Arizona	1. Commented that backpressure increase from muffler installation will cause an increase in fuel consumption	36
	2. Suggested that the regulation of railroad equipment in rural areas is not called for	40
R018 National Railroad Passenger Corporation CAMTRAK	1. Suggested separate regulations dealing with passenger related cars equipped with auxiliary power equipment	16
	2. Commented that diesel electric locomotives equipped with auxiliary power generators or twin traction engines, and gas turbine locomotives, may not be able to meet the idle standard	22
	3. Suggested that the moving locomotive standard should be speed related	26
	4. Suggested certain sound measurement parameters in the regulation	45
R019 Illinois Environmental Protection Agency	1. Questioned the absence of track and right-of-way standards in the proposed regulation	15
R020 Donaldson Company, Inc.	1. Commented that muffler costs will be higher than EPA estimates	34
	2. Commented that mufflers may cause excessive backpressure when applied to locomotives	36
	3. Commented on retrofit problems of certain types of locomotives	39
	4. Commented that muffling/silencing systems cannot be developed independently of the locomotive manufacturers	39

DOCKET NO. PERSON OR ORGANIZATION	COMMENT	PAGE NO. OF REPLY BY EPA IN DOCKET ANALYSIS
R021 Minnesota Pollution Control Agency	1. Questioned the absence of track and right-of-way standards in the proposed regulation	15
	2. Questioned the interpretation of the provision in the act for special local determinations	48
R023 Forestry Department, Salem, Oregon	1. Suggested that EPA consider the production and control of carbon particles in the locomotive exhaust	36
R024 Town of Bloomfield, New Jersey	1. Commented that inadequate information was provided as to the number of people impacted by railroad noise nor the number to be benefited by the regulation	40
	2. Requested that local railroad noise regulations not be prohibited by the EPA's regulatory action	48
	3. Requested that EPA impose property line standards on railroad noise	50
R025 General Motors Corporation (GM)	1. Commented on the proposed idle standard	20
	2. Questioned the validity of the 6dB(A) conversion factor for changing measurements made at 50 ft. to an equivalent 100 ft. value	51
	3. Commented that muffler installation will not always provide a 6dB(A) reduction of all locomotive noise levels	51
	4. Questioned the distance at which the measurements on noise emissions of an EMD 6P40-2 locomotive were made	52
R026 Mr. K. K. King	1. Commented that the proposed regulations would have a substantial adverse economic impact upon bankrupt railroads	35

DOCKET NO. PERSON OR ORGANIZATION	COMMENT	PAGE NO. OF REPLY BY EPA IN DOCKET ANALYSIS
R026 (cont.) King	2. Commented that adequate information as to the number of people impacted by railroad noise or benefited by the regulation was not provided	40
	3. Suggested that the regulation of railroad equipment in rural areas is not called for	40
R028 South Carolina Department of Health and Environmental Control	1. Suggested that railroad warning devices be regulated	4
	2. Commented that acoustic warning devices are not needed around railroad yards	6
	3. Suggested that the standards be reviewed periodically and strengthened as technological advances are made	49
R029 City of Chicago, Department of Environmental Control	1. Commented that the 100 ft. measuring distance in the standards is too far	46
	2. Commented on the interpretation of the provision in the act for special local determinations	48
	3. Suggested that local railroad noise regulations not be prohibited by the EPA's regulatory action	48
5030 Citizens Against Noise	1. Suggested the reduction of railroad warning devices through the authority of the noise control act	5
	2. Suggested that the regulation be made applicable to the operation of intraurban mass transit systems	19
5043 Mr. G.W. Kamperman, Kamperman Associates	1. Suggested that the C-scale would be more appropriate for this regulation than the A-scale	45

REFERENCES

(1). Altman, E.I. (1971). "Railroad Bankruptcy Propensity," *J. Finance*, Vol, XXVI, pp. 333-346.

(2). American Association of Railroad Superintendents (1972). "Computers – Who Needs Them?" Report of Committee No. 3, Annual Meeting.

(3). Baker, P.H., General Electric Co. (1973). Oral presentation before the Environmental Protection Agency and the Association of American Railroads, Washington, D.C., August 8.

(4). Bender, E.K. *et al.* (1974). "Railroad Environmental Noise: A State of the Art Assessment," Bolt Beranek and Newman Inc. Report No. 2709.

(5). Betts, W.F. (1973). "Verified Statement before the Interstate Commerce Commission in Support of Railroad's Petition for 5 Percent Increase in Freight Rates and Charges."

(6). Beranek, L.L., Ed. (1971). *Noise and Vibration Control*, New York: McGraw-Hill Book Co.

(7). Boline, J.J. (1973). "Illinois Central Gulf's Computerized Motive Power Accounting and Characteristics System (MACS)," *Railroad International*, October.

(8). Bolt Beranek and Newman Inc. (1973). "Contribution to Background Document for Rail Carrier Noise Regulations," Report to the EPA.

(9). Bolt Beranek and Newman Inc. (1975). "Comparison of Alternative Strategies for Identification and Regulation of Major Sources of Noise," Report No. 2966, prepared for the Environmental Protection Agency under Contract No. 68-01-1547.

(10). Burlington Northern Railroad Co. (undated). *Diesel Locomotive Diagrams.*

(11). Coelen, C. (1973). *Properties of the Adjustment Equation in a Model of the Demand for Workers.* Unpublished Ph.D. dissertation. Syracuse: Syracuse University Department of Economics.

(12). Fair, R.C. (1969). *The Short-Run Demand for Workers and Hours*, Amsterdam North Holland Publishing Company, 1969.

(13). Anon., "Retarders Are Key to Yards," Railway System Controls, June 1973.

(14). Altman, Edward I. (1971), "Railroad Bankruptcy Propensity," *Journal of Finance*, Vol XXVI, pp. 333-346.

(15). American National Standard Specification for Sound Level Meters, S1.4-1971.

(16). Bietry, M. (1973), "Annoyance Caused by Railroad Traffic Noise," Proceedings of a Congress on Traffic Noise, Grenoble, France, Jan. 9, 1973.

(17). DOT (1970), "A Study of the Magnitude of Transportation Noise Generation and Potential Abatement, Vol. V, Train System Noise," U.S. Department of Transportation Report No. OST-ONA-71-1.

(18). DOT (1971), "Noise and Vibration Characteristics of High-Speed Transit Vehicles," U.S. Department of Transportation Report No. OST-ONA-71-7.

(19). Embleton, T.F.W. and G.J. Thiessen (1962), "Train Noises and Use of Adjacent Land," *Sound,* I:1, pp. 10-16.

(20). EPA Docket 7201001.

(21). Friedlaender, Anne (1969), *The Dilemma of Freight Transportation Regulations,* Brookings Institution, Washington, D.C.

(22). Kendall, Hugh C. (1971), "Noise Studied in Retarder Yards," *Railway Systems Controls*, July 1971, pp. 9-13.

(23). Kurze, U. and L.L. Beranek, "Sound Propagation Outdoors" *Noise and Vibration Control*, edited by L.L. Beranek, McGraw-Hill, 1971.

(24). Kurze, U.J., E.E. Ungar, and R.D. Strunk (1971), "An Investigation of Potential Measures for the Control of Car Retarder Screech Noise," BBN Report No. 2143.

(25). Moody's Transportation Manual (1971).

(26). National Railway Publication Company (July 1973), *The Official Guide to the Railways.*

(27). Rand McNally & Co. (1971), *Commercial Atlas and Marketing Guide.*

(28). Railway System Controls (1972), "BN Studies Retarder Noise Abatement." *Railway System Controls,* November 1972, pp. 14-20.

(29). Rickley, E.J., R.W. Quinn, and N.R. Sussan (1973), "Wayside Noise and Vibration Signatures of High Speed Trains in the Northeast Corridor," Department of Transportation Report No. DOT-TSC-OST-73-18.

(30). Rapin, J.M. (1972), "Noise in the Vicinity of Railroad Lines. How to Characterize and Predict It," Centre Scientifique et Technique du Batiment, Cahiers, Building Research Establishment, Garston, Watford, WD2 75R.

(31). Ratering, E.G., "The Application of Vehicle Noise Test Results in the Regulatory Process," Conference on Motor Vehicle Noise, General Motors, April 3-4, 1973.

(32). Rathe, E.J. (1968), "Effect of Barriers on the Noise of Railroad Trains," Eidgenössiche Material Prüfungs–und Versuchsanstatt für Industrie, EMPA No. 38 155/2, Bübendorf (in German).

(33). Ringham, R.F. and R.L. Staadt, International Harvest Company Presentation to Environmental Protection Agency Office of Noise Abatement and Control, San Francisco, Calif., September 1971.

(34). Schultz, T.S. (1972), "Some Sources of Error in Community Noise Measurement." *Sound and Vibration*, 6:, 2, pp. 18-27.

(35). Schultz, T.S. (1971), "Technical Background for Noise Abatement in HUD's Operating Programs," Bolt Beranek and Newman Inc., Report No. 2005R.

(36). Ungar, E.E., R.D. Strunk, and P.R. Nayak (1970), "An Investigation of the Generation of Screech by Railway Car Retarders," BBN Report No. 2067.

(37). U.S. Bureau of Census, Census of Housing (1970), *Block Statistics, Final Report HC(3).*

(38). U.S. Bureau of Census, U.S. Census of Population (1970), *Number of Inhabitants, Final Report PC(1) – A1, United States Summary.*

(39). Wilson, G.P. (1971), "Community Noise from Rapid Transit Systems," in *Noise and Vibration Control Engineering*, Proceedings of the Purdue Noise Control Conference, July 14-16, 1971, p. 46, at Purdue University, Lafayette, Ind., edited by Malcolm J. Crocker.

(40). Wyle Laboratories (1973), Preliminary Data from Wyle Laboratories Research Project No. 59141, "Communities Noise Profiles for Typical Railroad Operations."

(41). "Business Week", McGraw-Hill, Inc., Sept. 8, 1923, p. 63.

(42). "Railway Age," Simmons Boardman Publishing Corp, Jan. 27, 1975, p. 68.

(43). Bolt, Beranek & Newman, Report No. 2709, "Rail Environmental Noise: A State of the Art Assessment," Cambridge, Mass.

(44). E.K. Bender and M. Heckl (1970), "Noise generated by Subways above Ground and in Stations," DOT Report No. OST-ONA-70-1 (January 1970).

(45). Federal Highway Administration and Federal Railroad Aministration (1971). "Report to Congress: Railroad Highway Safety, Parts I and II."

(46). Ferguson, C.E. (1969). *The Neoclassical Theory of Production and Distribution*, Cambridge University Press.

(47). Friedlaender, A. (1969). *The Dilemma of Freight Transportation*, Washington, D.C.: Brookings Institution.

(48). Frisch, R. (1965). *Theory of Production*, Chicago: Rand McNally & Co.

(49). General Motors Corporation (1974). "Locomotive Exhaust Muffler Retrofit; Cost Study Reports Nos. 1-4."

(50). Hultgren, T. (1960). *Changes in Labor During Cycles*, New York: New York National Bureau of Economic Research.

(51). Hoyt, H. (1968). *Urban Land Use Requirements, 1968-2000*, Homer Hoyt Institute, The American University, Washington, D.C., Research Monograph No. 1.

(52). Manvel, A.D. (1968). "Land Use in 106 Cities," in *Three Land Research Studies*, National Commission on Urban Problems, Research Report No. 12.

(53). McGaughey, R.S., Gohring, K.W., and McBrayer, R.N. (1973). "Planning Locomotive and Caboose Distributions," *Rail International*, November-December.

(54). Murray, R.F. (1971). "Lessons for Financial Analysis," *J. Finance*, May, pp. 3275-3332.

(55). New Jersey, State of. "Measurements of Locomotive Noise at Secaucus Shops, Erie Lackawanna Railroad," Docket submission to Department of Public Utilities, State of New Jersey, Docket No. 7312-1013.

(56). Osthoff, F.C. (1974). "Railway Motive Power – 1973," *Railway Locomotives and Cars*, New York: Simmons Boardman Publishing Corp.

(57). Peabody & Associates, Inc. (1974). "Analysis of the Costs of Compliance to the Proposed Interstate Rail Carrier Noise Emission Regulation," Report to the EPA.

(58). Pinkepank, J.A. (1973). *The Second Diesel Spotter's Guide*, Milwaukee: Kalmback Books.

(59). Primbramsky, R., General Motors Copr. (1973). "Diesel-Electric Locomotive Noise Emission," oral presentation before the Environmental Protection Agency and the Association of American Railraods, Washington, D.C., August 8.

(60). Remington, P.J., Rudd, M.J. and Ver, I.L. (1975). "Wheel/Rail Noise and Vibration; Vol. 2: Applications to Control of Wheel;Rail Noise," DOT Report UMTA-MA-06-0025-75-10.

(61). Rudd, M.J. and Blackman, E.S. (undated). "Computer Program for Predicting the Propagation of Railroad Noise," Bolt Beranek and Newman Inc. Technical Memorandum No. 199.

(62). Swing, J.W. and Pies, D.W. (1973). "Assessment of Noise Environments Around Railroad Operations," Wyle Laboratories Report WCR 73-5.

(63). Railway Equipment and Publication Co. (1973). *Railway Line Clearances*, Annual Issue.

(64). Rickley, E.J., Quinn, R.W., and Sussan, N.R. (1974). "Noise Land Measurements of Railroads: Freight Yards and Wayside," Department of Transportation Report No. DOT-TSC-OST-73-46.

(65). U.S. Environmental Protection Agency (1974a). "Background Document/Environmental Explanation for Proposed Interstate Rail Carrier Noise Emission Regulations," Report No 500/9-74-005a.

(66). U.S. Environmental Protection Agency (1974b). "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," Report No. 500/9-74-004.

(67). U.S. Interstate Commerce Commission (1972). *Eighty-Fifth Annual Report on Transport Statistics in the United States for the Year Ended December 31, 1971.*

(68). U.S. Interstate Commerce Commission (1974). *Class I Railroads, Financial and Operating Statistics for the Twelve Months Ended December 31, 1973;* Statement No. 100.

(69). Wilson, T.A. and Echsten, O. (1964). "Short-Run Productivity Behavior in U.S. Manufacturing," *Review of Economic and Statistics*, Vol. XLVI, pp. 41-54.

(70). Bellis, M.W., General Electric, from letter to BBN, Oct. 21, 1974.

(71). Kugler, Cummins, and Galloway, "Design Guide for Highway Noise Prediction and Control." Report NCHRP3 713, Transportation Research Board, National Academy of Sciences, November 1974.

(72). "Transport Statistics in the U.S.; Year ended December 1970; Part I, Railroads; Table 37, p. 15.

Railroad Contacts

Personnel in the operations departments of the following railroads were contacted in the course of this study.

AMTRAK
Atchison, Topeka, and Santa Fe
Baltimore and Ohio
Boston and Maine
Burlington Northern
Chesapeake and Ohio
Chicago, Milwaukee, St. Paul, and Pacific
Chicago and North Western
Chicago and North Western
Chicago, Rock Island, and Pacific
Denver and Rio Grande Western
Durham and Southern
Gulf, Mobile, and Ohio
Illinoise Central Gulf
Louisville & Nashville
Norfolk Southern
Norfolk and Western
Penn Central
Union Pacific

Yard superintendents, yard masters, or engineering department personnel with the following railroad companies were contacted in the course of this study.

Chicago, Milwaukee, St. Paul, and Pacific Railroad Yards,
Bensenville, Illinoise

Chesapeak & Ohio/Baltimore & Ohio Railraod Yard,
Walbridge, Ohio

Illinois, Central and Gulf Railroad Yard
Markham, Illinois and Centreville, Illinois

Norfolk & Western Railroad Yard,
Bluefield, West Virginia

Penn Central Railraod Yard,
Elkhart, Indiana

Boston and Maine Railroad Yard,
Mechanicville, New York

Southern Pacific Railroad Yard,
Roseville, California

Union Pacific Railroad Yard,
Cheyenne, Wyoming

Burlington Northern Railroad
Chicago, Illinois and St. Paul, Minnesota

Miscellaneous contacts in the railroad, or related, industry

Association of American Railroads, Research and Test Department
Washington, D. C.

General Electric Company
Erie, Pennsylvania

General Electric Company Sales
Chicago, Illinois

General Motors/EMD
Lagrange, Illinois

Appendix A

MAJOR TYPES OF DIESEL-ELECTRIC LOCOMOTIVES IN CURRENT U.S. SERVICE
(1 JANUARY 1973)

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Service Class I	Number In Service Class II
General Motors (Electro-Motive Division)	Switcher	NW2	1000	No	A	1119	39–49	721	137
		NW3,5	1000	No	A	20	39–47		
		SW1	600	No	A	660	39–56	628	117
		SW8	800	No	A	306	50–54		
		SW600	600	No	A	15	54–62		
		SW900	900	No	A	260	54–65		
		SW7	1200	No	A	493	49–51	1618	305
		SW9	1200	No	A	786	51–53		
		SW1200	1200	No	A	737	54–66		
		SW1000	1000	No	A	168⁺	66–	168⁺	--
		SW1500	1500	No	A	546⁺	66–	546⁺	--
	General Purpose Special Duty Road Switcher	GP/SD 7/7B	1500	No	B	2803	49–54	2550	133
		GP/SD 9/9B	1750	No	B	4072	54–59	3603	21
		GP/SD 18/28	1800	No	B	426	59–65	400	9
		GP 20	2000	Yes	C	335	59–62	300	7
		SD 24/2-3	2400	Yes	C	224	58–63	200	6
		GP 30/30B	2250	Yes	C	946	61–63	940	--
		GP/SD/35	2500	Yes	C	1645	63–66	1642	3
		GP/SD 38	2000	No	B	1103⁺	66–	1103⁺	3

Reproduced from best available copy.

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Service Class I	Number In Service Class II
General Motors (Electro-Motive Division)	Road Switcher	GP 39	2300	Yes	C	87	69–70	84	3
		GP/SD 40	3000	Yes	C	2217^{+}	66–	2213^{+}	4
		SD 45	3600	Yes	C	1362^{+}	65–	1362^{+}	--
		DD 35A/35B	5000	Yes	2C	45	63–65	45	--
		DDA 40X	6600	Yes	2C	47	69–71	47	--
	Streamlined	FTA/FTB	1350	No	B	1096	39–45	18	--
	Cab/Booster	F2A/F2B	1350	No	B	76	46		
	Freight/ Passenger	F3A/F3B	1500	No	B	1801	45–49	440	--
		F7A/F7B	1500	No	B	3982	49–53	1207	--
		F9A/F9B	1750	No	B	235	54–57	205	--
	Passenger Only	E7A/7B	2000	No	-	510	45–49	245	--
	(Twin Engines)	E8A/E8B	2250	No	-	457	49–53	226	--
		E9A/E9B	2400	No	-	144	54–63	88	--
General Electric	Switcher	44 ton	400	No	-	334	40–56	18	38
		70 ton	500-660	Yes	-	193	46–58		
		95 ton	500-660	Yes	-	46	49–56		
	Road Switcher	U25B/C	2500	Yes	D	591	59–66	524	--
		U28B/C	2800	Yes	D	219	66	219	--
		U23B/C	2250	Yes	D	212^{+}	68–	212^{+}	--

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Service Class I	Number In Service Class II
General Electric	Road Switcher	U30B/C	3000	Yes	D	470$^+$	66–	470$^+$	--
		U33B/C	3300	Yes	D	497	67–	497$^+$	--
		U36B/C	3600	Yes	D	157	69–	157$^+$	--
		U50B/C	5000	Yes	2D	66	63–70	66	--
Alco	Switcher	S1/3	660	No	-	653	40–53	92	36
		S6	900	Yes	E	100	55–60		
		T6	1000	Yes	E	55	58–69		
		S2/4	1000	Yes	E	2012	40–61	681	233
	Road Switcher	RS1/RSD1	1000	Yes	E	497	41–60		
		RS2	1500	Yes	E	400	46–50	75	5
		RS2/3	1600	Yes	E	1312	50–56	564	30
		RSD4/5	1600	Yes	E	203	51–56		
		RS11/12/36	1800	Yes	D	436	56–63	345	11
		C415	1500	Yes	D	26	66–68	26	--
		RS32 C-420	2000	Yes	D	164	61–68	131	[illegible]
		RSD7/15	2400	Yes	D	102	54–60	115	--
		RS27 C-424	2400	Yes	D	90	59–67		--
		C-425	2500	Yes	D	91	64–66	85	--
		C-628	2750	Yes	D	135	63–68	31	--

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Service Class I	Number In Service Class II
Alco	Road Switcher	C-430/630	3000	Yes	D	93	66-68	84	--
		C-636	3600	Yes	D	34	67-68	31	--
	Streamlined Cab/Booster	FA/FB1	1500	Yes	-	581	46-50	--	--
		FA/FB/2	1600	Yes	-	491	50-56	--	--
		PA/PB1	2000	Yes	-	210	46-50	--	--
		PA/PB1/2/3	2250	Yes	-	84	50-53	--	--
Baldwin Lima Hamilton	Switcher	S-8	800	No		61	50-54	22	15
		DS-4-4-10	1000	Yes		433	46-51	136	46
		S-12	1200	Yes		449	51-56	190	38
	Road Switcher	RS-12	1200	Yes		46	51-56		
		DRS-N-16 RS-N16	1600	Yes		447	47-55	36	29
	Streamlined	RF16/16B	1600	Yes		160	50-53		
Fairbanks Morse	Switcher	H10-44	1000	No		197	44-49	40	6
		H17-44	1200	No		306	50-53	164	9
	Road Switcher	H16-44/66	1600	No		384	50-63	105	--
		H24-66	2400	No		105	53-56	31	--
Whitcomb	Switcher		600					--	5
Plymouth	Switcher		300					1	3
Cooper Bessemer	Switcher		1200						7

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Service	
								Class I	Class II
[illegible]			0					21	--
Cummins	Switcher		470						4
H.K. Porter	Switcher		500						[illegible]

REVIEW OF THE USE OF AUDIBLE TRAIN MOUNTED WARNING DEVICES AT PROTECTED RAILROAD - HIGHWAY CROSSINGS

B.1 Requirements For the Use of Audible Warning Devices

The stopping distance of trains is much longer than that of motor vehicles, they are much more difficult to reaccelerate, and due to their length they often overlap more than one road intersection at a time. Therefore, trains have traditionally had the right-of-way at level crossings, while motorists are expected to look out for trains and give way. The burden is then placed upon the railroad to assist the motorist in determining when a train passage is imminent. The traditional method of doing this is to sound a whistle and/or bell and keep a headlight burning on the head ends of all trains, and to mark the crossing in some manner so as to attract the attention of approaching travelers.

Public Railroad-Highway grade crossings may be equipped with one of the following, which are classified herein into the three major headings shown:

(a) Unprotected

(1) Unilluminated stop-look-listen sign or "cross buck" at the crossing generally accompanied by striping and words painted on the road surface and passive prewarning signs in advance of the crossing.

(2) As above, plus continuous (night time) illumination of the crossing and/or the signs.

(3) As above plus flashing amber caution lights.

(4) Any of the above, plus "rumble strips" on the road surface.

(b) Protected (no gates)

This group of systems may employ combinations of the signs, lights, markings, etc. from (a) above, but is distinguished by the addition of:

(1) Flashing lights generally plus bells, which are actuated upon the approach of the trains(s) by virtue of automatic electrical signals attached to the tracks. These systems are arranged to be fail-safe, in that most internal failures cause the signal to indicate the approach of a train.

(2) Traffic lights may be used in some places, in lieu of the characteristic flashing crossing lights, but also conveying the intelligence that a train(s) is in fact in the vicinity.

(3) Watchmen, stationed at the crossing, or trainmen walking with their train, will "flag" motorists or may activate lights or other devices.

(c) Protected With Gates

In addition to active signals and advance warnings as in (b) physical barriers are automatically dropped in the motorists' path upon the approach of the train(s), often with lights attached thereto.

These gates may interrupt only the approaching highway lanes (half gates) or both lanes on each side (to discourage driving around) and may be supplemented by small pedestrian gates at walkways. However, these gates are not constructed so as to physically restrain vehicles, but are really a type of "sign", intended to assure driver attention and realization that a train is to be expected. Gates are commonly used at busy crossings where there are two or more tracks, to add a degree of protection against motorists proceeding as soon as one train has passed, when there may be one approaching on another track.

The cost of installation of crossing signals varies widely and depends greatly upon particular local circumstances. Modest installations with gates average about $30,000, and may be as high as $60,000. The annual cost of inspecting, maintaining, and repairing protected crossings is about $1,000 each, not including the cost of roadway and track work.

Complete grade separations may cost hundreds of thousands of dollars, or even millions, and while many are being constructed, the number is not statistically significant within the context of the overall problem. (When separations are installed, it is usually possible to arrange for the outright closing of a few nearby crossings, thus expanding the safety benefit of this large investment.)

The level of crossing protection installed at a particular location is determined by the hazard involved which is effected by the amount of road traffic, the number and speed of trains passing and topography. This may be determined by the judgement of local officials, the railroad managements, or both and is often established simply by a past record of accidents at a crossing in question. The investment in crossing equipment may be the responsibility of the railroad, the State or local government, the Federal government or any combination thereof. This question has been the subject of much controversy in the past, and is in a state of flux at present, with the trend being toward greater government responsibility although some railroads continue to spend large sums of their own money on new systems every year. Automatic signal system maintenance has always been the responsibility of the railroad.

Train-born signals to warn motorists and pedestrians of the approach of trains are required by most States. Federal safety regulations are confined to the inspection of such devices on locomotives, to the end that - if present - they shall be suitably located and in good working order (Safety Appliance Act, 45 USCA; 49 Code of Fed. Regulation 121, 234, 236, 428, 429). The Federal government has shunned greater regulatory responsibility in this field in the past. There is a very significant

Federal research and promotional effort underway to improve grade corssing safety, however.

The State laws requiring train-born signals do not quanlify their loudness. It is common for the State laws to quatify the requirement to apply all public crossings except in municipalities, leaving the use of horms or bells in towns and cities to local discretion.

A survey of the 48 contiguous States yields the following summary of information regarding their regulations:

.. Requirements for sound signals at public crossings imposed by:

Statute	38
Public Utility Commission	1 (Calif.)
Common Law	3
Penal Code	1 (N. Y.)
None or no information	5
	48

.. Requirement at private crossing: - if view is obstructed 1

.. Signals to consist of:

Whistle or bell	24
Whistle and bell	7
Whistle	6
Bell only	2 (Fla. & R.I.)(a)

(a) Florida restriction to bells applies in incorporated areas and is accompanied by a speed restriction of 12 mph.

.. Distance at which signal is to be sounded:

Beginning at a minimum of distance (35 States varying from 660 feet in Michigan to 1500 feet in South Carolina, with an average of 1,265, the most common being 1,320 feet (80 rods).

Beginning at a maximum distance (3 States): Montana 1,320, Ohio 1,650, and Virginia 1,800 feet.

To continue until train:

Reaches crossing	35
Is entirely over crossing	3

.. Exception of some form provided for incorporated areas in at least 15 States:

California, Lowa, Indiana, Kentucky, Michigan, Minnesota, Missours, New Jersey, New York, Nevada, Utah, Virginia, Washington, Wisconsin, and Florida.

.. Exception provided at crossing with:

Gates and/or watchmen - Delaware

Flashing lights and bells - Illinois

(More is said about exceptions in a later section of this report.)

Railroad operating rules reflect the ordinances in effect in the areas through which they pass, generally encouraging the use of warning signals at the discretion of the operator to avoid accidents, but admonishing against unnecessary soundings. Specific supplementary advice is contained in Standard Rule 14, which is adopted by many carriers, requiring the sounding of signals in all situations where two or more trains are at or approaching a crossing simultaneously, due to the extra hazard consequent to the limited view and preoccupation of approaching motorists and pedestrians when they see or hear just one of the trains.

Two good examples of State requirements for the sounding of warning signals at crossings are those of California and West Virginia, attached hereto as Appendix A1, A2, and B, respectively.

Over and above statutory and regulatory requirements for the use of warning signals on trains, the judiciary and juries have tended to assume that there is a burden upon the operators of railroads to employ such devices. Numerous judgments have been made against railroads in court cases wherein the sufficiency of warnings were questioned, particularly by juries and seemingly to a relatively greater degree in California. As a result, railroads are reluctant to dispense with any ordinary action which might be construed to be a contributing factor in crossing accidents. More will be said on this topic in a later section.

In addition to requirements for warning travellers at level crossings, the State of New Jersey Public Utilities Commission has ordered that passenger carrying railroads operating in that State sound a horn or whistle prior to stopping at or passing through a passenger station on a track adjacent to a platform. (January 20, 1972, Docket 7010-525) Subsequent modifications limited this requirement to one long blast, during daylight hours, and then only when the engineer has reason to believe persons may be in the vicinity of such platforms.

B.2 Railroad - Highway Accidents

There are over 220,000 public rail highway crossings at grade in the United States, of which 22% are actively protected (Categories 2 and 3). (There are also about 150,000 private crossings.)

In 1972 there were almost 12,000 public crossing accidents, resulting in 1,260 deaths. These totals have been decreasing slowly since 1966. In 67% of these accidents the train struck a motor vehicle, in 28% a motor vehicle struck trains and in 5% trains struck pedestrians or there

NOTE: Figures in this section are taken from references (4) and (5). Accident figures sometimes differ between references due to the $750 cost baseline for reporting accidents to the Federal Railroad Administration. Crossing figures may differ due to the inclusion or exclusion of private crossings.

were no trains involved. 39% of the collisions occurred at crossings provided with gates, watchman, audible and/or visible signals, while 61% were at crossings having signs which did not indicate the approach of trains (Category 1).

63% of the collisions occurred during daylight, and 37% at night. It is believed that about 67% of motor vehicle traffic flows in the daytime, 33% at night, suggesting a slightly higher crossing hazard at night (37% of the collisions with 33% of the traffic).

Automobiles constituted 73% of the motor vehicles involved, trucks 25%, motorcycles 1.3% and buses 0.3%.

When motor vehicles struck sides of trains, they usually contacted the front portion thereof, particularly during daylight; the propensity to strike elsewhere increases at night. The side of train category appear to be twice as hazardous at night, in that 53% of them occur then, with 33% of the traffic, with the peak occurring between midnight and 2 a.m. In fact, when these are deducted from the total, the train-strikes-vehicle collisions are in about equal proportion to the traffic distribution, day and night.

The propensity for accodents at actively protected crossings is also greater at night than in daylight, per unit of traffic, perhaps indicating that driver alterness is a more significant factor in these cases.

TABLE 1. SUMMARY OF PUBLIC CROSSING TYPES, LOCATIONS AND ACCIDENTS (1970)

	URBAN	RURAL	TOTAL
GATES (category 3)	5970	2970	8940
SIGNALS (category 2)	18050	14620	32670
OTHER OR MANNED	4240	2680	6920
TOTAL ACTIVE	28260	20270	48530
(ACCIDENTS)	(3624)	(1533)	(5157)
PASSIVE (category 1)	50860	12385	17471
(ACCIDENTS)	(3827)	(3428)	(7255)
GRAND TOTAL	79120	144120	223240
(ACCIDENTS)	(7451)	(4961)	(12412)

There were 70 fatalities in 1972 at gates, and 440 total at all active crossings, somewhat less than one per 100 crossings.

Accident rates and severity are significantly higher at actively protected crossings, indicating that the greater hazards where they are installed are not fully compensated for by the increased protection. The rates are also higher in urban areas than rural, for both active and passive crossings, so that in the very areas where noise exposure is greatest, the safety situation is worst.

It could also be argued that the accidents which occurred in spite of the active protection demonstrate the ineffectiveness or waste of warnings such as train horns in such areas.

While vehicle traffic, train traffic and speed continue to increase, protection installations are also increasing, and the total number of crossings is decreasing. The 1973 Highway Act provides a total of $175 million over a three year period for crossing safety, on a 90/10 Federal share basis, or a potential total of $193 million, of which at least half is to be spent on active protection systems. Gate installations constitute about 30% of all new protection, and since such systems cost about $30,000 on the average, approximately 1,000 more gate installations should occur during this three year period, in addition to those installed at railroad initiative. The Northeast Corridor is already on its way to being totally without level crossings of any kind.

NOTE: Reports of crossing statistics vary from year to year, are often based on different reporting criteria and may be for either public and private crossings.

B.3 The Impact and Effectiveness of Locomotive Horns

Acoustical Characteristics and Noise Impact

The audibility of air horns, the predominant warning devices which are the subject of attention herein, has been investigated (1) as part of a DOT program to make crossing warning systems more effective. It was found that the horns which are presently employed are not very effective, and to be so it would be necessary to increase their loudness, "warbling" and/or the use of as many as 5 chimes (pitches) have been recommended. Obviously, since the whole purpose is to gain attention and instill a sense of imminent danger and alertness in persons located at 1/4 mile distance, such signals are bound to be disturbing - by definition.

Figure 1 shows the approximate noise pattern of an average locomotive horn. In order to increase motorist impact to a degree sufficient to be of real value, the loudness would need to be increased as much as 23 dB, resulting in a loudness of 128 dB at 100 feet. (The A and C weighted loudness of the common air horns are almost identical; no distinction is made in the literature).

Loudness at 90° from the direction of movement is 5 to 10 dB less than straight ahead and it is possible that this pattern could be improved somewhat, but the loudness should be substantially maintained to at least 30° each side of center due to the variation in angle of approach of railroads and highways.

This problem of audible warning is shared with emergency vehicle sirens. Fire, police and rescue units have a parallel problem. With motor vehicle windows closed, in modern, acoustically well constructed vehicles, and with road noises and/or air conditioning, radios, etc. competing with the warning devices, at least 105 dB is needed outside a vehicle in order to gain the attention of most drivers. Research is underway to determine the feasibility of installing warning devices inside motor vehicles, which would be actuated by the approach of a train or an emergency vehicle.

In Figure 1 are shown the acoustical characteristics of the common railroad air horns, the orientation of train and vehicles in a set of relatively high speed encounters, such that the motor vehicles shown would have a reasonable stopping distance to the point and instant of train passage at a crossing. Table 2 lists the required noise levels at vehicles travelling at various speeds (exterior background noise assumed dominated by running noise of vehicle) to gain the attention of the drivers; the 50% attention column nearly corresponds to the average

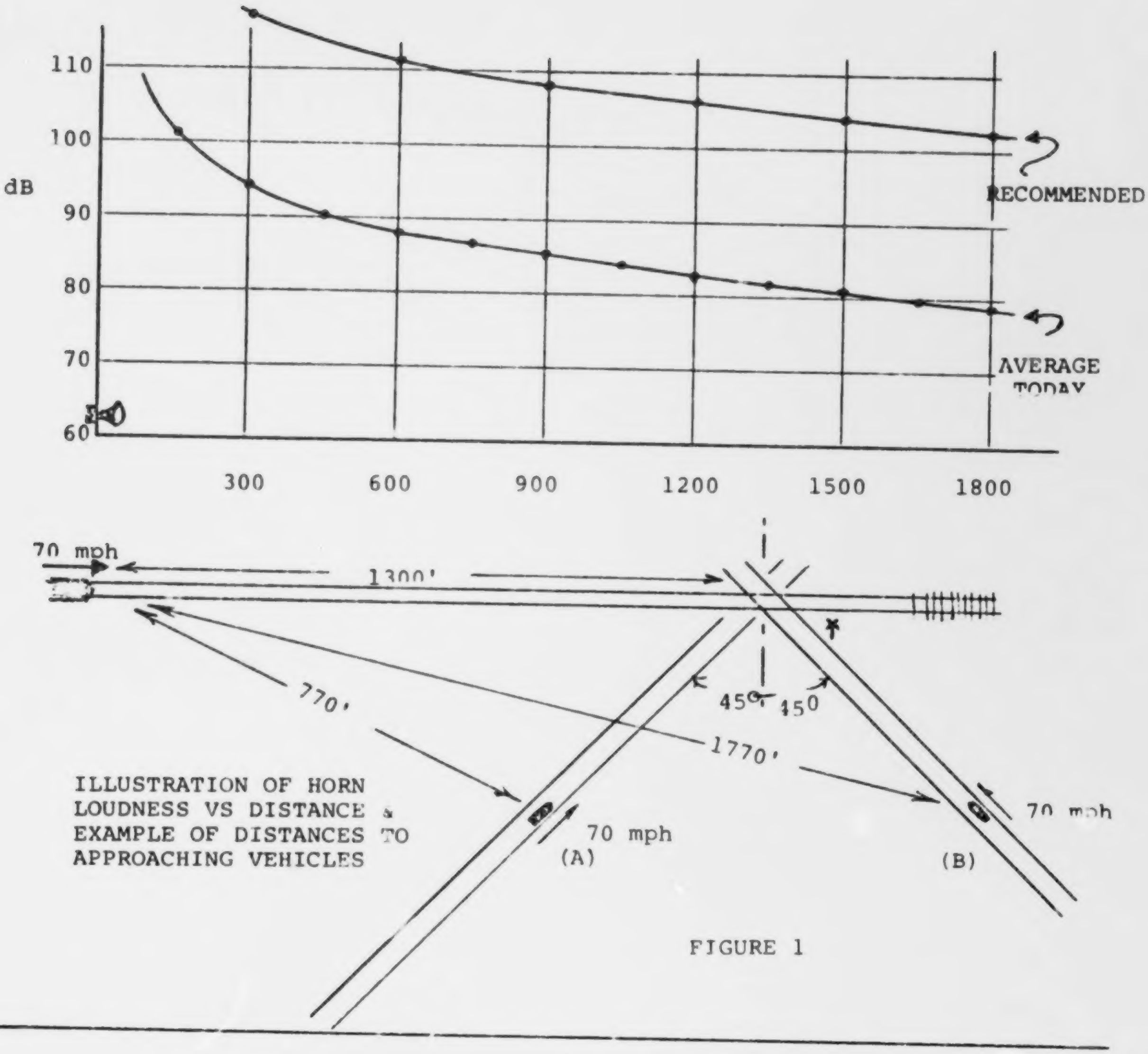


ILLUSTRATION OF HORN LOUDNESS VS DISTANCE & EXAMPLE OF DISTANCES TO APPROACHING VEHICLES

FIGURE 1

TABLE 2

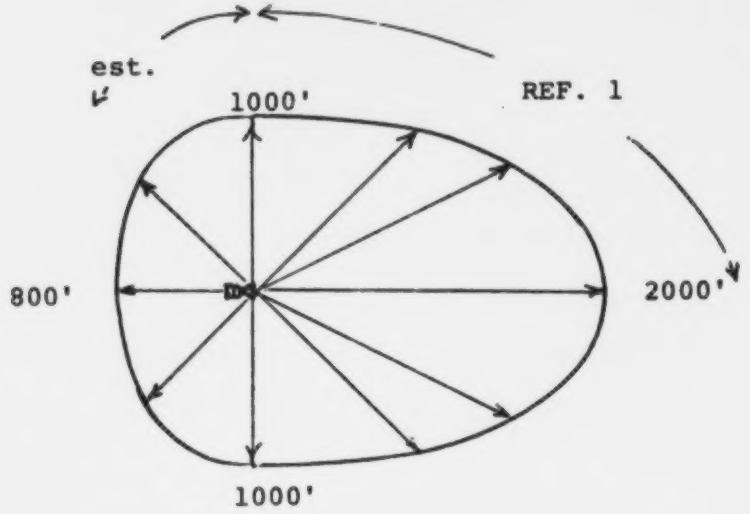
VEHICLE SPEED	dB OUTSIDE VEHICLE FOR % FOR DRIVERS TO NOTICE	
	50%	98%
≥ 35 mph	83	101
36 - 50 mph	87	105
51 - 65 mph	91	109

(SOURCE: REF 1) STANDARD DEVIATION - 6dB situation today. To alert 98% of the drivers at (B) it would be necessary to increase the sound levels by about 30 dB, resulting in a level at 100 feet abreast of the locomotive of about 130 dB.

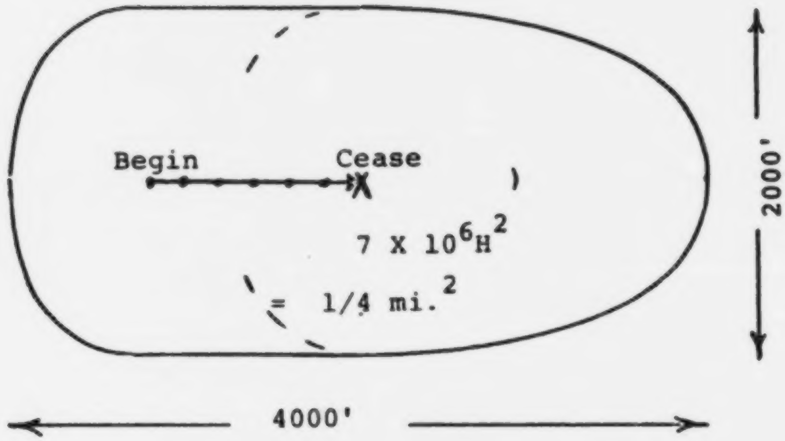
Figure 2(a) illustrates the noise pattern which characterizes most horns in use today, and Figure 2(b) depicts the areas lying within an envelope in which the noise from a horn being blown for a crossing will equal or exceed 77 dB for some period with each train passage. The 77 dB figure is chosen rather arbitrarily, largely because it corresponds to a 1,000 foot boundary adjacent to the track, which is compatible with the modest data available on residential population alongside railroads. It is also a reasonable number as regards nuisance levels of intermittent noise intrusion, being used herein merely for the purpose of approximating the scope of the impact of warning device noise.

Some 202 miles of railroad route in 12 areas of 10 cities of varying overall size, selected randomly, have been reviewed. The population within 1,000 feet of the railroads in this examination average 2,410. Therefore, in urban areas, about 600 persons are usually exposed to 77 dB from an instant up to 10 or 15 seconds each time a train passes a level crossing.

LOCOMOTIVE HORNS - AVERAGE NOISE PROPAGATION UNDER IDEAL CONDITIONS


est.
REF. 1
1000'
800'
2000'
1000'

a) 77 dB Profile


Begin
Cease
7 X 10^6H^2
= 1/4 mi.^{2}
2000'
4000'

b) Area subjected to 77dB level or more
Based upon extension of profile along route

FIGURE 2

Table 3

			% of Population
1.	Unprotected	33.0 million	16
2.	Signalled	13.7	6
3.	Gated	(3.7)	(2)
	Total	46.7 million	22

(Signalled includes gated)

This would indicate that one-fifth of the total population is "within hearing" of a grade crossing. In fact, the noise patterns are probably much less severe than shown here, due to topographical features, and many of the protected as well as some of the unprotected crossings are covered by restrictive ordinances, so that probably more like 10-15% of the people are exposed to the 77 dB or greater level used here for illustration (exterior to dwellings, etc.).

If the use of horns was prohibited at all actively protected crossings, 30% of these exposures would be avoided. If such a restriction was confined to crossing with gates, 8% of the exposures would be avoided. These abatement measures would be noticeable to about 3% or 1% of the population, respectively, allowing for attenuation locally and background noise and the fact that many crossings are already covered by such rules.

Assuming that the use of signals and gates corresponds to the highest hazard levels or volume classes as depicted by the Department of Transportation, the number of daily train and vehicle passages at the crossings in question has been estimated as shown in Table 4.

Table 4

	Daily Trains	Daily Vehicles
Total over signalled crossings	950,000	160,000,000
Average per signalled crossing	20	3,300
Total over gated crossings	200,000	70,000,000
Average per grated crossing	22	7,800

If the average train sounds its horn over a period of 12 seconds, the average citizen within 1,000 feet will experience the noise at 77 dB or more for an average of 8 seconds. At gated crossings where horn blowing occurs 22 times per day, the equivalent energy produced (L_{eq}) is 50.1 dB, whereas at signalled crossings where it occurs only 20 times per day, the equivalent energy would be 49.7 dB.

People residing within hearing of grade crossings are generally conditioned to the sound, which tonewise is not particularly disturbing. The most common casual notice of the use of horns at crossings is expressed by persons staying at motels, which are not infrequently located on highways which parallel railroads and are near road crossings. Being otherwise unaccustomed to the sound, it is quite noticeable, particularly at night.

Warning Effectiveness of Horns

As noted above, at present only about half of all motorists can notice the sound of a train horn when they are driving and their windows are closed, even under ideal conditions. And the alerting capability - even if the horn is noticeable - is still less. It is impossible to determine how many accidents have been prevented by the routine sounding of horns, although it is apparent from the experience of train drivers that many accidents have been averted by the ad hoc sounding of horns, while an even greater number have occurred in spite of it. However, these comments are directed to all crossings, passive (unprotected) as well as active (protected). It is unlikely that either routine or ad hoc use of horns at crossings where lights are flashing and bells are ringing at the crossing significantly improves ordinary driver attention, particularly where gates are lowered as well. On the other hand, some drivers and most pedestrians can hear the horn when it is sounded. Also, in those occasional incidents where a vehicle is stalled on a crossing the horn may serve to divert people from continued efforts to move their vehicle and to depart forthwith on foot. But in the latter case, sounding on a routine basis is probably not necessary.

Attached hereto as Enclosures C, D, and E are (abridged) reports on three rather typical grade crossing accidents wherein the accidents occurred in spite of crossing signals and the sounding of warnings by the train. These are selected somewhat randomly, to illustrate by example a kind of crossing accident which is all too common.

B.4 Prohibition against the use of audible devices

It is already quite common for the routine sounding of horns or whistles to be prohibited, except in emergencies. It is also common for these prohibitions not to be enforced. A careful search for cases where such prohibitions appeared to, or were claimed to contribute to an accident has not yielded evidence of a single such situation.

Among the localities which restrict the use of horns are those listed in Table 5.

Table 5. Some Localities with Restrictions

	Notes
The State of Florida	(2)
The State of Illinois	(1)
The State of Massachusetts	
Chicago, Illinois	(1) (2) (3)
Houston, Texas	(1) (2)
Minneapolis, Minnesota	
Buffalo, New York	(1) (2)
Philadelphia, Pennsylvania	
Knoxville, Tennessee	(1) (2)
Durham, North Carolina	(2)
Mason City, Iowa	(3)
Warren Pennsylvania	
Elkhart, Indiana	
Toledo, Ohio	
Columbus, Ohio	
Akron, Ohio	
Lynchburg, Virginia	(1) (2)
San Bernadino, California	(1)
South Holland, Illinois	
Elmhurst, Illinois	
Lockport, N.Y.	
Rochester, N.Y.	

(1) Contacted local authorities in course of this study.

(2) Specific Information contained in Enclosure F.

(3) Not enforced.

The 15 states where requirements to use horns are excepted, but not necessarily prohibited, in incorporated areas are:

Table 6.

California*
Florida
Iowa*
Kansas
Kentucky*
Michigan*
Minnesota
New Jersey
New York*
Nevada*
Utah
Virginia*
Washington
Wisconsin

(*also have local-option provision)

In 4 additional states there is a local option provision, allowing cities and towns to relieve requirements:

Table 7.

Illinois
Indiana
North Carolina
West Virginia

Two states permit silent running at crossings with certain protection systems:

.. Delaware: warning requirements do not apply when crossing is protected by watchman or gates.

.. Illinois: requirements do not apply when crossing is protected by automatic signals (with or without gates).

One of the most comprehensive Noise Control Regulations thus far drafted in the United States is that of the State of Illinois. As it stands, its property line limitations would affect the use of audible crossing warning devices except that its Rule 208, Exceptions, states: "Rules 202 through 207 inclusive shall not apply to sound emitted from emergency warning devices and unregulated safety relief valves."

Thus, it can be seen that there is considerable precedent for placing constraints upon the use of audible warnings, with no apparent adverse effects. However, they are not uniformly enforced, and where enforced, the carrier generally receives written instructions from the constraining authority, and is nevertheless impowered to sound warnings "in emergencies"..."in the event of impending accident"... etc.

B.5 Judicial Background

Tort litigation constitutes the bulk of the legal or judicial history of grade crossing safety responsibility. Abstracts of 2500 cases throughout the United States during the period 1946 to 1966 have been surveyed (3), checking into 300 possibly related to the question at hand.

In addition, 5 cases were cited by a cooperating railroad as illustrative of the railroad liability question. One of these was found to be inapplicable to the question at hand, three were decided in favor of the railroad. In the other, a jury found for the plaintiff, although a whistle had in fact been sounded. Of these, 21 appeared to be somewhat related and the case records were reviewed. Nothing was unearthed which would appear to deter Federal or local constraints on audible traincarried devices at protected crossings.

Several themes are woven through the opinions rendered in the many cases on record. These are certainly not uniformly respected, but they are sufficiently common as to be noticeable:

.. Safety provisions, including warnings, should be compensurate with the specifics of local conditions.

.. The railroad is expected to give "adequate and timely" warning of the approach of a train. The railroad's case is often intended to show that their warning could have been heard by an attentive motorist.

.. To be cause for placing liability, an omission on the part of the carrier generally must be shown to have contributed to the event in question.

.. Motorists are generally expected to be cautious at crossings, to the extent even of stopping or look "and listen".

.. Contributory negligence on the part of a motorist is generally taken into account.

The fact remains, however, that courts, especially juries, have extracted severe payments from railroads, seeming usually to give plaintiffs the benefit of all doubt. For this reason, railroad companies are understandably at pains to make any changes which could conceivably be construed as a reduction in safety precaution (or increase in hazard). Also, the employees charged with operating trains are usually subject to prosecution under criminal law if negligence and/or violation of a statute might be involved, and are thus inclined to err in the direction of sounding their warning devices, not to mention their sincere personal desire to avoid injury to even the negligent public, as well as themselves. (Collision between trains and large trucks, especially those carrying hazardous materials, are very dangerous to the occupants of the train.) A possible fine for violation of a noise ordinance is not nearly as imposing a threat as the liablility, criminal action and conscience which accompany the threat of collision.

B.6 Summary

One of the railroad noise sources which has been commented upon in the course of interstate rail carrier regulatory development by this Agency's Office of Noise Abatement and Control, is that of railroad train horns which are sounded routinely at grade crossings. It has been suggested that such sounding be prohibited in cases where automatic, active protection is in operation at the crossing itself, particularly where this protection includes gates.

However, it remains that the routine sounding of horns might be contributing to the prevention of some accidents. Certainly, a small segment of the population is exposed to serious noise intrusion thereby and a reduction in their welfare, particularly at night. But it is the Agency's position at this time, that it would be imprudent to single out and restrict night time use of horns, since the crossing hazard with regard to driver behavior is, if anything, worse at night.

In view of the questionable value of train horns for warning highway drivers, particularly at locations having active crossing signals, it may be appropriate to encourage the abolition of routine use of horns at crossings so equipped, particularly but not necessarily only those with gates. The circumstances which determine hazard levels as well as noise intrusion vary widely and are peculiar to local circumstances. It is therefore concluded that regulation of railroad warning be best left to the option of local authorities at this time, recommending thereto that consideration be given to restrictions upon the routine sounding of train horns at protected crossings.

REFERENCES

1. The Visibility and Audibility of Trains Approaching Rail-Highway Grade Crossings; J. P. Amelius, N. Korobow; NTIS-PB-202668.

2. Driver Information Systems for Highway-Railway Grade Crossings; K. W. Heathington, T. Urbanik.

3. American Digest System, 6th and 7th Dicennial Digests.

4. Rail Highway Grade Crossing Accidents from the Year 1972, Department of Transportation, Federal Railroad Administration.

5. Report to Congress on Railroad-Highway Safety, No. II, Department of Transportation, FRA/FHWA.

Public Utilities Code Annotated of the
State of California
Adopted May 31, 1951
Page 784

ARTICLE 8
CRIMES

Collateral References

§7678. Omission to sound bell or whistle. Every person in charge of a locomotive-engine who, before corssing any traveled public way, omits to cause a bell to ring or steam whistle, air siren, or air whistle to sound at the distance of at least 80 rods from the crossing, and up to it, is guilty of a misdemeanor.

Legislative History

Enacted 1951. Based on former Pen C §390, as amended by Stats 1949 eh 391 § 1 p 733, without substantial change.

Collateral References

Cal Jur 2d Railroads 44
McKinney's Cal Dig Railroads § 71.
Am Jur Railroads S S 357 et seq.

PUBLIC UTILITIES CODE, STATE OF CALIFORNIA
(Abridged)

7604. A bell, of at least 20 pounds weight, shall be placed on each locomotive engine, and shall be rung at a distance of at least 80 rods from the place where the railroad crosses any street, road or highway, and be kept ringing until _it_ has crossed the street, road, or highway; _or_ a steam whistle, air siren, or an air whistle shall be attached, and be sounded _except in cities_, at the like distance; etc.

ENCLOSURE B

THE WEST VIRGINIA CODE

(Abridged)

§ 31-2-8. Warning of approach of train at crossings; crossing railroad tracks.

A bell or steam whistle shall be placed on each locomotive engine, which shall be rung or whistled by the engineer or fireman, at a distance of at least sixty rods from the place where the railroad crosses any public street or highway, and be kept ringing or whistling for a time sufficient to give due notice of the approach of such train before such street or highway is reached, and any failure so to do is a misdemeanor punishable by a fine of not exceeding one hundred dollars; and the corporation owning or operating the railroad shall be liable to any party injured for all damages sustained by reason of such neglect.

I. SCOPE OF STATUTE AS TO WARNINGS.

A. In General.

Michie's Jurisprudence. — For full treatment of accidents at crossings, see 15 M.J., Railroads, §§ 69-101. As to duty to give signal by bell or whistle, see 15 M.J., Railroads, §§ 81-83.

ALR references. — Railroad company's negligence in respect to maintaining flagman at crossing, 16 ALR 1273; 71 ALR 1160.

Duty of railroad company to maintain flagman at crossing, 24 ALR2d 1161.

Admissibility of evidence of train speed prior to grade-crossing accident, and competency of witness to testify thereto, 83 ALR2d 1329.

The common-law requirement as to signals is fully as exacting as the statutory duty. What the notice and warning to the public shall be depends, under the common law, upon the circumstances of each case; but some adequate methods of apprising travelers of the crossing must be practiced. Niland v. Monongahela & West Penn Pub. Serv. Co., 106 W. Va. 528, 147 S.E. 478 (1928).

Both bell and whistle are not required without statute. — There is no absolute requirement upon a railroad company to blow a whistle and ring a bell at a crossing unless made so by statute. Niland v. Monongahela & West Penn Pub. Serv. Co., 106 W. Va. 528, 147 S.E. 478 (1928).

The methods of apprising travelers of a crossing almost universally adopted are by the ringing of a bell or the sounding of a whistle, but in order to make both obligatory, the use of both must be called for by a statute. Niland v. Monongahela & West Penn Pub. Serv. Co., 106 W. Va. 528, 147 S.E. 478 (1928).

Provisions of section are minimum requirements. — The provisions of this section as to warning signals are of broad application and are minimum requirements, and in every case the compliance with this statute, plus the presence of an efficiently operating crossing-bell will not (apart from the question of contributory negligence of the plaintiff) constitute an ironclad defense to the railroad, under all circumstances. Baltimore & O.R.R. v. Deneen, 161 F.2d 674 (4th Cir. 1947).

Travelers have the right to assume that trains will give the usual signals at crossings. Morris v. Baltimore & O.R.R., 107 W. Va. 97, 147 S.E. 547 (1929).

But railroad only owes duty to signal as required by statute. — The driver of an automobile on a public crossing is an invitee, and the railway company is bound only to use reasonable care not to collide with the automobile, and owes only the duty to give the signals provided by statute. Chesapeake & O. Ry. v. Hartwell, 142 W. Va. 318, 95 S.E.2d 462 (1956).

As this section is intended to protect persons on highway. — The duty imposed by statute to sound a bell or whistle when approaching a public crossing does not require a railroad company to give such warning elsewhere than at the places so designated, because they are not intended to afford protection to employees of the operating company, but to persons who of right may use the railroad tracks as parts of the public highway. Jones v. Virginian Ry., 74 W. Va. 666, 83 S.E. 54, 1915C L.R.A. 428 (1914).

II. FAILURE TO GIVE WARNINGS AS NEGLIGENCE; CONTRIBUTORY NEGLIGENCE.

Violation of section is negligence. — The failure to give proper signals of the approach of a train to a railroad crossing as required by this section would constitute negligence on the part of a defendant railroad. Cavendish v. Chesapeake & O. Ry., 95 W. Va. 490, 121 S.E. 498 (1924).

But does not impose liability unless it proximately causes injury. — Liability for injury to baby of 13 months could not be based on failure to give signals since the failure was not the proximate cause of the injury. Virginian Ry. v. Armentrout, 158 F.2d 358 (4th Cir. 1946).

Failure to ring the bell or blow the whistle at crossings, though required by law, will not render the company liable, unless that be the proximate cause of the injury. Beyel v. Newport News & Miss. Valley R.R., 34 W. Va. 538, 12 S.E. 532 (1890).

Thus, railroad is not liable if contributory negligence is proximate cause. — Where one is injured by carelessly driving on a railroad crossing in front of a moving engine or train, the proximate cause of his injury must be regarded as his contributory negligence, and not the negligence of the railroad company in failing to ring the bell or blow the whistle. Cline v. McAdoo, 85 W. Va. 524, 102 S.E. 218 (1920).

Where the only evidence was that the warning signals required by this section were not given, and that the failure to do so constituted negligence on the part of defendant, it was held that notwithstanding defendant's negligence, if deceased's contributory negligence is established as a matter of law, plaintiff can have no recovery. Arrowood v. Norfolk & W. Ry., 127 W. Va. 310, 32 S.E.2d 634 (1944).

And signal requirement does not relieve traveler of exercising ordinary care. — Failure to ring bell or blow a whistle on an engine, as required by this section, is negligence for which a railroad company is chargeable, but this does not excuse the traveler on a highway crossing a railroad track from the exercise of such reasonable care and caution as the law requires, to ascertain whether a train is approaching the crossing. Beyel v. Newport News & Miss. Valley R.R., 34 W. Va. 538, 12 S.E. 532 (1890); Bassford v. Pittsburg, Cincinnati, Chicago & St. Louis Ry., 70 W. Va. 280, 73 S.E. 926 (1912); Cline v. McAdoo, 85 W. Va. 524, 102 S.E. 218 (1920); Robinson v. Chesapeake & O. Ry., 90 W. Va. 411, 110 S.E. 870, 22 A.L.R. 892 (1922); Cavendish v. Chesapeake & O. Ry., 95 W. Va. 490, 121 S.E. 498 (1924); Gray v. Norfolk & W. Ry., 99 W. Va. 575, 130 S.E. 139 (1925); Berkeley v. Chesapeake & O. Ry., 43 W. Va. 11, 26 S.E. 349 (1896).

Though a traveler has the right to assume that warning signals required by this section will be given, failure to give them will not excuse him from exercising ordinary care, and taking the necessary precautions for his safety. Arrowood v. Norfolk & W. Ry., 127 W. Va. 310, 32 S.E.2d 634 (1944).

III. EVIDENCE.

The burden of proving that signals were not given rests upon the plaintiff. Parsons v. New York Cent. R.R., 127 W. Va. 619, 34 S.E.2d 334 (1945).

No conflict in evidence where some witnesses heard signals and some did not. — The fact that witnesses have heard signals given by a locomotive approaching a crossing warning travelers of danger, is not necessarily in conflict with the evidence of other witnesses who did not hear them; for the observation of the fact by those who heard is consistent with the failure of the others to hear them. Cavendish v. Chesapeake & O. Ry., 95 W. Va. 490, 121 S.E. 498 (1924).

Unless witnesses not hearing had equal opportunity to do so. — Testimony with reference to the statutory warning signals which only goes so far as to establish that the witnesses did not hear the bell rung and the whistle sounded is not in conflict with the testimony of other witnesses who testified that in fact the whistle was blown and the bell rung. An exception to the foregoing rule arises where there was equal opportunity of a witness to hear the signals and special circumstances or events directed the attention of the witness to the failure to give them. Holiman v. Baltimore & O.R.R., 137 W. Va. 874, 74 S.E.2d 767 (1953).

Witnesses in position to observe but not hearing signals are entitled to peculiar weight. — Where the witnesses were in a position to observe with unusual care the circumstances surrounding the accident, their testimony as to the neglect to sound the customary warnings by bell or whistle, or both, within a reasonable distance from the crossing, a duty dictated by reason and required by this section, is entitled to peculiar weight. Casdorph v. Hines, 89 W. Va. 448, 109 S.E. 774 (1921), citing Carnefix v. Kanawha & Mich. R.R., 73 W. Va. 534, 82 S.E. 219 (1914); Southern Ry. v. Bryant, 95 Va. 213, 28 S.E. 183 (1897).

Thus, denial that signals were given may produce jury question. — The testimony of one witness, who denies that a railroad whistle was sounded on a given occasion, is as positive evidence as the testimony of another who affirms the fact, where each has equal opportunity of hearing and the attention of the former because of special circumstances is equally drawn with that of the latter to the sounding of the whistle. The denial by the one and the affirmance by the other produces a conflict of evidence, which it is the province of the jury to determine. Tawney v. Kirkhart, 130 W. Va. 550, 44 S.E.2d 634 (1947).

Whether a conflict arises between positive and negative evidence of this character depends upon the facts and circumstances of each case, from which it may be determined whether such negative evidence has any probative value. Cavendish v. Chesapeake & O. Ry., 95 W. Va. 490, 121 S.E. 498 (1924); Tawney v. Kirkhart, 130 W. Va. 550, 44 S.E. 634 (1947).

Since, if evidence conflicts, question is for jury. — Where the evidence as to blowing the whistle and ringing the bell is in conflict, the question of fact is one to be determined by the jury. Kelley v. Kanawha & Mich. Ry., 99 W. Va. 568, 130 S.E. 677 (1925); Tawney v. Kirkhart, 130 W. Va. 550, 44 S.E.2d 634 (1947).

Where the evidence conflicts and is credible, the question is one for the jury. Parsons v. New York Cent. R.R., 127 W. Va. 619, 34 S.E.2d 334 (1945).

Where the evidence conflicts as to whether proper signals by ringing bells or blowing whistles were given, the court cannot say that the verdict of the jury is not supported by the evidence. Coleman v. Norfolk & W. Ry., 100 W. Va. 679, 131 S.E. 563 (1926).

Question of traveler's contributory negligence held for jury. — See Arrowood v. Norfolk & W. Ry., 127 W. Va. 310, 2 S.E.2d 634 (1944).

Evidence held insufficient to submit railroad's negligence to jury. — In action for injuries sustained in crossing collision evidence was insufficient to justify submission to jury of question of railroad's negligence in failure to comply with this section. Baltimore & O.R.R. v. Deneen, 161 F.2d 674 (4th Cir. 1947).

Evidence held sufficient to sustain verdict for either party. — Conflicting evidence on question of whether railroad gave statutory warning signals required by this section was sufficient on both sides to have sustained a verdict in favor of either party. Tawney v. Kirkhart, 130 W. Va. 550, 44 S.E.2d 634 (1947).

Evidence held to favor railroad's compliance with section. — In Krodel v. Baltimore & O.R.R., 99 W. Va. 374, 128 S.E. 824 (1925), there was some conflict of testimony as to sounding the whistle and ringing the bell at a railroad crossing, but it was held that the weight was in favor that the defendant complied with the statute.

ENCLOSURE C

MULTIDISCIPLINARY ACCIDENT INVESTIGATION

Case No. UC852D

(Abridged)

Prepared by

University of California
Los Angeles, California

The contents of this report reflect the views of the performing organization which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, specification or regulation.

UCLA COLLISION INVESTIGATION PROGRAM

VEHICLE COLLISION REPORT

Prepared for the U.S. Department of Transportation
National Highway Safety Bureau,
Under Contract FH-11-6690

Certain information contained in this report is obtained from indirect sources.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily of the National Highway Safety Bureau.

1. STANDARD CASE SUMMARY

1.1 SUMMARY TEXT

IDENTIFICATION: This train versus automobile collision occurred on a Thursday at 10:51 a.m. at a combination intersection/railroad crossing in California. Maximum occupant injury severity: critical (06) Collision causation: driver inattention.

AMBIENCE: Day; weather clear and dry; roadway dry.

ROADWAY: A straight, asphalt, undivided roadway, 75 ft. wide with curbs, in a suburban area with speed limit of 35 mph. The collision site is at a railroad crossing, 25 feet before a T-intersection. The road has a negligible crown, and is upgrade at the site. The roadway has three intersections within one-quarter mile of this intersection.

TRAFFIC CONTROLS: The lanes are separated by broken white lines with opposing lanes divided by double-double yellow lines. There is a railroad automatic signal and a traffic signal at the railroad crossing. There were no crossing gates at the time of the collision. Four auto/train collisions at this site in past 3 yrs

VEHICLES: Vehicle #1: Freight train weighing approximately 400 tons. Vehicle #2: 1967 Cadillac Coupe de Ville two-door hardtop with power windows and seat. No apparent defects. Collision damage to right door causing intrusion of 12". Occupant contact with intruding door and train. Deformation Index: 03RPMW2.

OCCUPANTS: Vehicle #2: Driver: 59-year-old female, height, 64", weight, 160 lbs. Lap belt in use. No HBD or drugs. Injuries: fractured rib, lumbar back strain, abrasions, and contusion.

Right Front: 63-year-old female. No restraint in use. No HBD or drugs. Injuries: compound, depressed skull fracture with cerebral contusion, abrasions and contusions over body.

DESCRIPTION:

Pre-collision: Vehicle #2, the Cadillac, approaching the T-intersection, failed to stop at the railroad crossing in spite of the warning lights and bell. Slowing for the red light at the intersection, the Cadillac entered the tracks, into the path of the train. The train was eastbound at approximately 15 mph, approaching the crossing. The train engineer was sounding the whistle and applied his brakes when he saw the Cadillac in crossing.

Collision: The train struck the Cadillac in the right side, pushing it 150 ft. along the railroad tracks. The Cadillac remained in a position at a right angle to the railroad tracks. Occupants of the Cadillac moved to the right, and the right front occupant was struck by the intruding train.

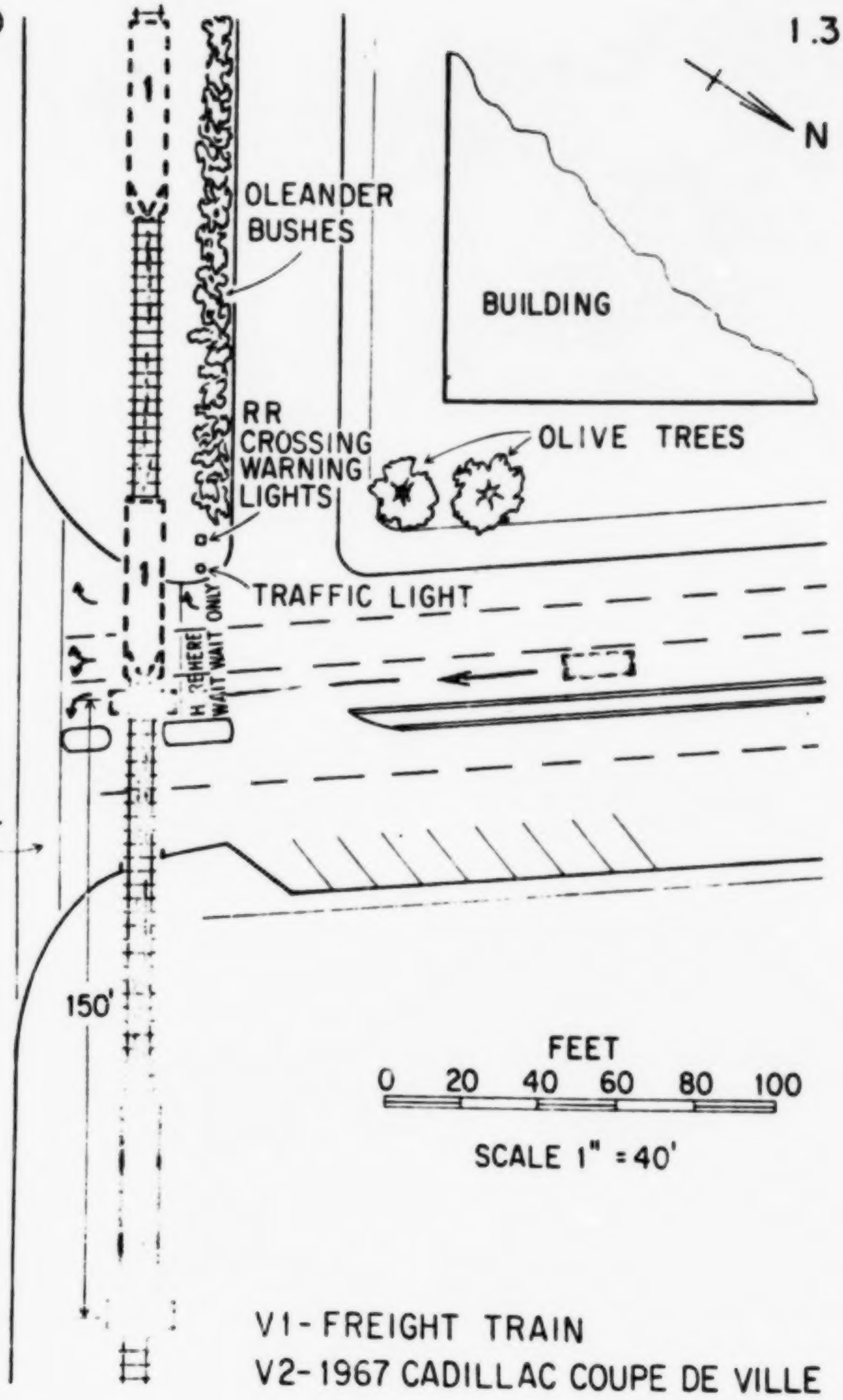
Post-collision: Occupants were hospitalized. Railroad crossing gates were later installed at the crossing.

1.2 CAUSAL FACTORS, CONCLUSIONS, RECOMMENDATIONS:

Matrix cell (*indicates positive factor)	Explanation
1	Driver inattention and/or distraction appear to be the chief cause of this collision.
4	Air conditioning on, with windows rolled up, makes it difficult to hear train or warning bells.
5	Right door penetration of 12" due to side impact. Door metal torn in area of hinges.
5	It is recommended that integrated side structures be employed, combining strength of frame, door sill, body pillars and roof.
5*	Right door latch and hinges did not fail.
7	Driver's view of oncoming train partially blocked by shrubbery along tracks.
7	Vehicles were allowed to stop on railroad tracks while waiting to turn at intersection.
7	It is recommended that visibility of oncoming trains be maximized by removing obstructions. Vehicles should not be allowed to wait on railroad tracks.
8*	Railroad crossing gate was installed and light locations were altered after the collision.

U.C. # 852D

1.3


N
OLEANDER BUSHES
BUILDING
RR CROSSING WARNING LIGHTS
OLIVE TREES
1
1
TRAFFIC LIGHT
WAIT HERE
WAIT ONLY
WAIT HERE
CROSS-WALK
150'
FEET
0 20 40 60 80 100
SCALE 1" = 40'

V1 - FREIGHT TRAIN
V2 - 1967 CADILLAC COUPE DE VILLE

ENCLOSURE D

SOUTHWEST RESEARCH INSTITUTE

CASE SUMMARY
(MV-TRAIN–INTERSECTION COLLISION)
Case No. 7173

(Abridged)

IDENTIFICATION

This accident occurred at the MKT railroad grade crossing on Eisenhauer Rd. at IH35 in San Antonio, Bexar County, Texas, on Thursday, September 30, 1971 at 1335 hours, involving the collision of a diesel freight engine and a 1970 four-door station wagon with a lone driver. The westbound automobile was struck on its left side by the northbound locomotive. The area is residential. The accident was injury-producing; AIS Severity Code No. 3.

AMBIENCE

It was daytime with partly cloudy skies, 85°F dry bulb, 57 percent relative humidity, 10-mph breeze blowing from the southeast, the road surfaces were dry and clear of debris and loose gravel.

HIGHWAY

Eisenhauer Rd. is a major access artery between the interstate loop expressway system and the residential areas of northeast San Antonio. It is a 41-ft-wide, four-lane, two-way roadway with an asphalt surface of the intermediate type in good condition. The road is divided at this immediate area of the IH35 access road - Eisenhauer Rd. intersection by 6-in.-high concrete channelizing islands. The traffic lanes are 10 ft wide. Eisenhauer Rd. runs east-west and is bounded on both sides by a 6-in. curb. The road is straight and level. It is not crowned. The coefficient of friction on the dry surface was 0.61. A southbound, one-way, two-lane 24-ft-wide frontage road runs 60 ft east and parallel to a mainline, single track railroad right-of-way, both intersecting Eisenhauer Rd. at this point. An exit ramp from IH35 is immediately north of this intersection and an entrance ramp is immediately south. These ramps connect IH35 to the frontage road.

TRAFFIC CONTROLS

The posted speed limit on Eisenhauer Rd. is 30 mph. The speed limit is 40 mph on the frontage road. A railroad company-imposed speed limit of 25 mph is assigned for 0.5 mile each side of the crossing. Traffic control devices consist of pavement markings, 6-in.-high channelizing islands, regulatory, warning, and guide signs. There are two flashing amber lights, 36-in.-diameter yellow railroad advance warning signs, and black-on-white railroad crossbucks. There are neither traffic control signal(s) in the area nor a flashing red light or bell warning signals, gates, or guards to provide immediate warning of an approaching train.

VEHICLES

No. 1. 1968 GP40 Electromotive diesel freight engine. The 3-yr-old engine is considered to be in good operating condition with no indicated defects. Minor secondary damage includes bent brakeman's steps, bent coupling actuator lever, and airhose torn loose, secondary vehicle deformation index 12FDLW1. The retail repair cost was nil.

No. 2. 1970 Oldsmobile Vista Cruiser, four-door, three-seat, yellow station wagon; odometer reading 22,224 miles; valid Texas Motor Vehicle Inspection sticker with a damaged illegible date; equipped with a standard 350-cu in. eight-cylinder gasoline engine; automatic transmission, power steering, and power front disc-type brakes; radio, heater, air conditioner, and tape deck; padded armrests, sunvisor, seat back tops, interior rearview mirror, windshield interbeam, and instrument panel. Three seatbelts and two shoulder straps for front bench-type seat and three seatbelts for the second bench-type seat. The shoulder straps were in the stored position. No defects were apparent or indicated. The last vehicle maintenance w performed at 13,663 miles on January 21, 1971 and included lubrication and oil and filter change. Primar contact damage was 16-in. sheet metal and frame deformation to the left side, primary vehicle deformati index 09LPAW5. Secondary damage was to the tires, rear bumper, and roof. The retail replacement val was $3075 (total less $200 salvage value).

OCCUPANTS

Vehicle No. 1. Engineer: 46-yr-old white male, 71 in., 155 lb (estimated). An interview was n obtained. He was familiar with the vehicle and the route traveled.

Injury: None.

Vehicle No. 2. Occupant No. 02. Driver: 42-yr-old white female of Latin-American extraction, 62 in., 132 lb. She has been driving 20 yr and currently drives approximately 9000 miles/yr. She was en route from her husband's office to home, a distance of 10 miles. The accident occurred 1 mile from her destination. She had no definite ETA. She was familiar with the vehicle and with the route traveled. She has had no formal driver's education. Her physical condition was excellent. Her precrash state was rested with no stress; she was inattentive to her driving task. Lap and shoulder restraints were available, but not in use.

Injury. Severe (not life-threatening). AIS Severity Code No. 3.

STANDARDS

The following Highway Safety Program Standards (HSPS) and/or Motor Vehicle Program Standards (MVPS) were relevant to this case:

HSPS No. 4–*Driver Education Use of Occupant Restraints, Radio, and Failure to Look for Train*
HSPS No. 9–*Identification and Surveillance of Accident Locations*
HSPS No. 13–*Traffic Control Devices*
MVPS No. 201–*Occupant Protection in Interior Impact*
MVPS No. 214–*Side Door Strength.*

DESCRIPTION

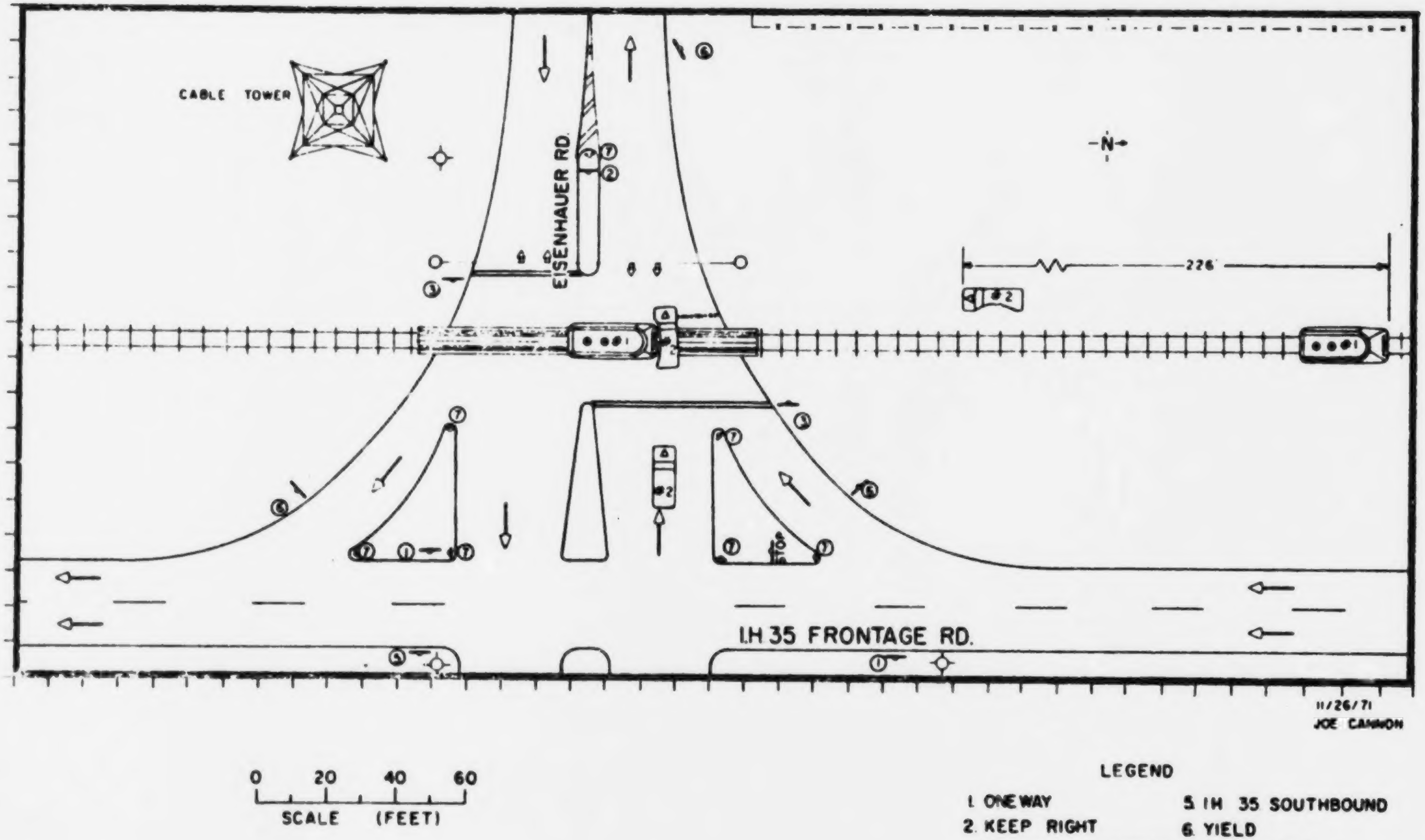
Precrash: The driver of vehicle No. 2 (passenger car) was traveling to her home from her husband's office. She had left northbound IH35 and turned west onto Eisenhauer Rd., passing under the IH35 overpass. She crossed the southbound frontage road at a relatively low speed (estimated not more than 25 mph) and drove in front of vehicle No. 1 (diesel freight engine), which was moving north at about 25 mph with its horn blowing for the crossing. There were no skidmarks from vehicle No. 2 prior to impact. The car radio was in operation.

Crash. Impact occurred on the left side of vehicle No. 2, centered approximately at the "A" pillar line, as it crossed the railroad track in front of vehicle No. 1. The coupler of the freight engine forced in the forward portion of the door structure, firewall, cowl, and instrument panel structure. Other portions of the front structure of the engine–brakeman's steps and brackets–forced in the doors, floor, and frame left siderail to a depth of 16 inches. The passenger vehicle was pushed northward on the railroad right of way. It then yawed left and came to rest 88 ft from the impact point, parallel to and 7 ft west of the tracks facing the crossing. The unrestrained driver was first thrown left against the incaving side structure of the car. Then she was thrown to the right. Vehicle No. 1 stopped 314 ft from the point of impact.

Postcrash. The driver of vehicle No. 2 was not ejected from the vehicle. She was removed from vehicle No. 2 through the right front door without complications. She was taken to the hospital by ambulance approximately 20 min after the crash. Because the automobile came to rest a considerable distance from the roadway, there was no appreciable interference with traffic. A wrecker had no complications in picking up the vehicle and towing it away. Since the locomotive was not significantly damaged, it was able to proceed. Traffic on Eisenhauer Rd. was estimated at 15 vehicles/min; on the frontage road, traffic was estimated at 5 vehicles/min.

CAUSAL FACTORS, CONCLUSIONS, AND RECOMMENDATIONS

Matrix Cell (* Indicates Positive Factors)	Explanation
1	Driver No. 02 was inattentive and did not observe normal precautions when approaching the railroad track.
1	Driver No. 02 had her radio on and windows up, which may have prevented or seriously interfered with her ability to hear the train's signal horn.
1	The engineer may have been speeding, with respect to the company-imposed limit of 25 mph, 40 to 50 mph. This is the situation if the train brakes were adequate and if the engineer maintained a locked brake mode throughout the stopping sequence.
2	Driver No. 02 was not wearing the available seatbelt or shoulder strap.
3	Driving in a veil of interior noise (radio, air conditioner, etc.) with the windows closed should be discouraged in driver education programs.
4	The train should have been capable of stopping within 104 ft from 25 mph. The 314-ft stopping distance, from the point of impact, suggests that either the driver did not fully apply the brakes at some point during the collision sequence or that the brakes were not performing adequately.
*5	Occupant injuries from impact against interior surfaces and protuberances were mitigated as a result of adequate padding and interior design.
7	This site has an extremely high accident rate; however, more adequate traffic control by a train-approach signal system has not yet been authorized.


CABLE TOWER
EISENHAUER RD.
-N-
226'
#1
#2
I.H 35 FRONTAGE RD.
STOP
11/26/71
JOE CANNON
0 20 40 60
SCALE (FEET)

LEGEND

1 ONE WAY
2 KEEP RIGHT
3 RAILROAD CROSSBUCK
4 NO PARKING ANYTIME
5 IH 35 SOUTHBOUND
6 YIELD
7 REFLECTOR

COLLISION SCENE SCHEMATIC

ENCLOSURE E

Maryland Medical-Legal Foundation

Office of the Chief Medical Examiner

State of Maryland

Truck/Train Impact

Case # MMF 72-24

(Abridged)

MULTIDISCIPLINARY ACCIDENT INVESTIGATION SUMMARY

IDENTIFICATION OF COLLISION

The highway is a state road traversing north and south in the southeast portion of an industrial section of Baltimore County. The accident occurred in September of 1972 at 0400 hours on a Friday involving a tractor trailer and a freight train at a front to side impact. The accident caused fatal injuries to the driver of the tractor trailer.

INJURY SEVERITY SCALE: Driver of Vehicle #1 FATAL-AIS-8

AMBIENCE

Night; no illumination; misty; 58 degrees F.; 60% relative humidity; wind 10 m.p.h. from the northwest; visibility of 500 feet; road surface was wet; coefficient of friction .55 dry (measured) and .45 wet (estimated).

HIGHWAY

The highway on which the accident occurred is a major arterial state road with a total width of 106 feet consisting of two 12 foot lanes going north and two 12 foot lanes going south divided by a 48 foot grass median. The roadway is of black top macadam with an 8 foot shoulder on the east side and a 2 foot shoulder on the west side. The roadway is straight and level. There is no artificial lighting and within ½ mile there are two intersections; one being 800 feet south of the railroad crossing and the other being 600 feet north. There are 9 telephone and transit poles within ½ mile. The accident history at this point within a year previous is 6 property damage and 3 personal injury accidents with an average daily traffic of 22,500 vehicles.

TRAFFIC CONTROLS

The speed limit is posted at 55 m.p.h. and there are intermittent lane lines with solid edge lines painted in the roadway. There are standard railroad crossing signs and lights at the right side of the road with overhead signals actuated by the train

VEHICLES INVOLVED

Vehicle #1 was a 1969 G.M.C. Tractor, two-door, red in color with an odometer reading of 49,760 miles. There is no inspection data but the vehicle was well maintained by the company garage. The vehicle was equipped with manual steering, manual transmission, air brakes (drum type), seat belts (being used by the driver when the accident occurred). There was no previous damage noted. Damage to Vehicle #1 on impacting the train at an eleven o'clock principal impact force was to the left front causing a sheet metal crush of 38 inches. The bumper, grille, fender and hood deformed rearward into the engine compartment whereby the engine separated from mounts. The left front wheel and assembly moved rearward. The seats moved forward and the driver impacted the steering wheel and column with his chest and his head impacted the left A-Pillar as it was deformed inward and rearward. After the initial impact a second impact of 06 hours principal force occurred as the trailer sheared from the fifth wheel and impacted the rear of the cab with a sheet metal crush of 18 inches compressing the cab interior by 50% pinning the operator in.

VEHICLE DEFORMATION INDEX: Principal Impact - 11 FLAW-4
Secondary Impact - 06 BDHW-4

Vehicle #2 was a General Motors E.M.D. type locomotive pulling 47 box cars and it sustained minor damage to the right front side.

VEHICLE DEFORMATION INDEX: 02 RFMW-1

OCCUPANT DATA

The driver of Vehicle #1 was a 46 year old white male, 68 inches tall, weighing 115 pounds having 30 years driving experience at approximately 15,000 miles per year. At the time of accident he was enroute from his place of employment with a delivery for a distant city expected to arrive 5 hours after the accident occurred. The accident occurred within 5 miles from the origin. He was familiar with the vehicle and the area having used both daily for the past several years. His physical condition was normal as was his mental condition. There was no alcohol or drug involvement and seat belts were available and in use by the operator. During the accident the driver sustained the following injuries: fractures of skull, ribs, pelvis and extremities, contusions of lungs with hemothorax, laceration of heart, laceration of liver and spleen with hemoperitoneum, rupture of bladder; and contusions of hippocampi and temporal lobe of brain. (AIS-8)

The driver of Vehicle #2 (train) was a 57 year old white male, weight and height unknown having 40 years driving experience with 15 years as a railroad engineer. His driving record is good with 10,000 miles per year plus rail usage undetermined. He is familiar with the engine using same three to four times weekly. At the time he was shifting cars along the railroad from yard to yard. His engineering ability was taught to him by the railroad company. There were no drugs or alcohol involved. There were no restraints available and no injuries. There were three passengers on the train and they were not injured or restrained. Passenger #1 was a white male, 56 years of age and he was seated in the front center. Passenger #2 was a white male, 36 years of age and he was seated in the front right. Passenger #3 was a white male, 54 years of age and he was seated in the rear left.

STANDARDS

1. FHSPS #9 - Identification and Surveillance of Accident Locations. The railroad crossing is well protected with traffic signals actuated by the train, but it is so little used that drivers attempt to beat the train. It is recommended that gates be installed at the railroad crossing.

COLLISION DESCRIPTION

Pre-Crash

The driver of Vehicle #1 reported to work at the usual time, 0130 hours, and had proceeded from the terminal to deliver a load of hardware to a distant city. He was operating the vehicle northbound on a state road at an estimated speed of 45 to 50 m.p.h. and when he approached the east/west railroad crossing he failed to stop for the signals and collided with the right front side of a slow moving freight train. The freight train was proceeding eastbound at an approximated speed of 8 to 10 m.p.h. There is no evidence to show that the driver of Vehicle #1 tried to take any evasive action, however, the operator of the train did apply his air brakes for an emergency stop.

Crash

Vehicle #1 impacted the right front side of the train with its left front at an eleven o'clock principal force impact with a secondary impact force of 06 o'clock when the trailer sheared off the fifth wheel and impacted the rear of the truck cab. As the vehicle rotated 25° clockwise, and coming to rest 42 feet east of the impact, the driver, who was restrained, moved forward and to the left impacting the steering wheel and the left A-Pillar and was impacted from the rear by the cab body and seat.

Vehicle #2 was impacted at the right side at front initial impact force at 02 o'clock deforming the entrance steps and the hand rail. The unrestrained occupants were well to the rear of the impact point and suffered no effects of the accident. The driver of the train applied his air brakes for an emergency stop and the train remained on the rails coming to a stop 168 feet east of the impact.

Post-Crash

Vehicle #1 came to rest 42 feet east of the impact facing east off the roadway and Vehicle #2 came to rest 168 feet east of the impact, on rails. The operator and passengers of Vehicle #2 were unhurt. The operator of Vehicle #1, due to the compression of the truck cab from the front and rear impacts, was pinned in the cab. Emergency rescue equipment of the Police and Fire Departments were called, responding within 10 minutes and proceeded to cut the metal attempting to free the driver. Due to severe deformation, extrication was difficult and took two hours to free the driver. He was pronounced dead at the scene and was taken to the Office of the Chief Medical Examiner. During the rescue operation, traffic was tied up in both directions and suitable detours were maintained by the police. A two company was contacted to clear the scene of the truck and debris. The truck was towed to the terminal and the train was moved under its own power. The scene was cleared and open for traffic within four hours.

CAUSAL FACTORS, CONCLUSIONS AND RECOMMENDATIONS

ACCIDENT CAUSATION

Matrix Cell	Explanation
	Primary Cause
1	Driver of Vehicle #1 failed to perceive the approaching train and danger of going through signals. (Definite)
	Severity Increasing
1	Driver of Vehicle #1 made no attempt at evasive action. (Definite)
	Relevant Conditions
1	Driver of Vehicle #1 was apparently preoccupied with thoughts of his trip. (Probable)
7	The crossing was well protected with actuated signals (at side and overhead) but it allows room for passage. (Probable)

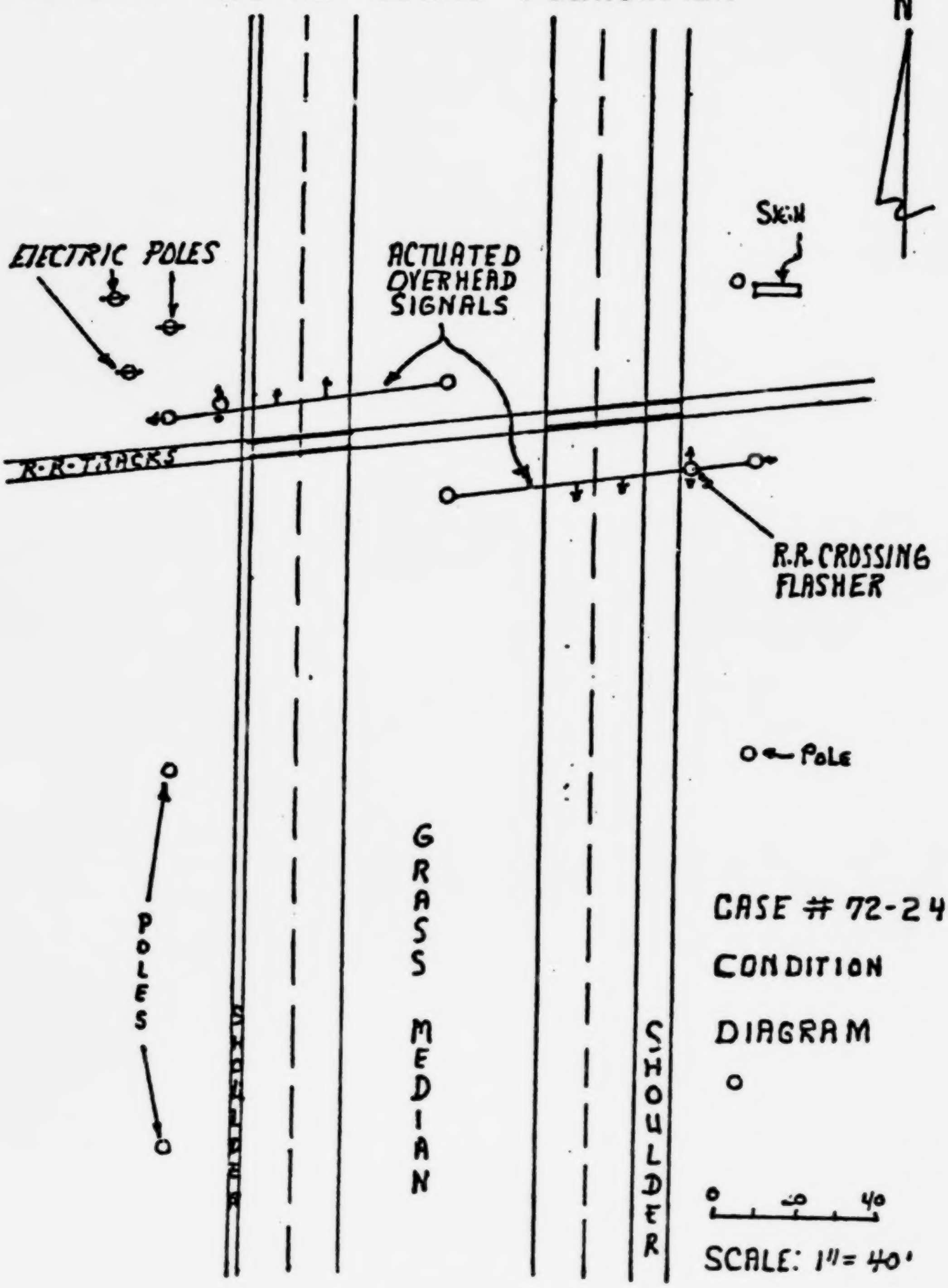
INJURY CAUSATION

Matrix Cell	Explanation
2	Driver of Vehicle #1 was wearing available restraints but they were of no use in this case. (Probable)
5	The collapse of Vehicle #1 from front and rear impacts added to severe injury. (Definite)

POST-CRASH FACTORS

Matrix Cell	Explanation
3	Ambulance and rescue arrival within 10 minutes, but extrication was difficult taking two hours with metal saws. (Definite)
6	The load of Vehicle #1 shifted after the initial impact. (Definite)
9	There were no fires or explosions, detours were set and maintained adequately, and the clean-up operation took four hours. (Definite)

MARYLAND MEDICAL- LEGAL FOUNDATION


N
SIGN
ELECTRIC POLES
ACTUATED OVERHEAD SIGNALS
R.R. TRACKS
R.R. CROSSING FLASHER
POLE
POLES
SHOULDER
GRASS MEDIAN
SHOULDER
0
20
40

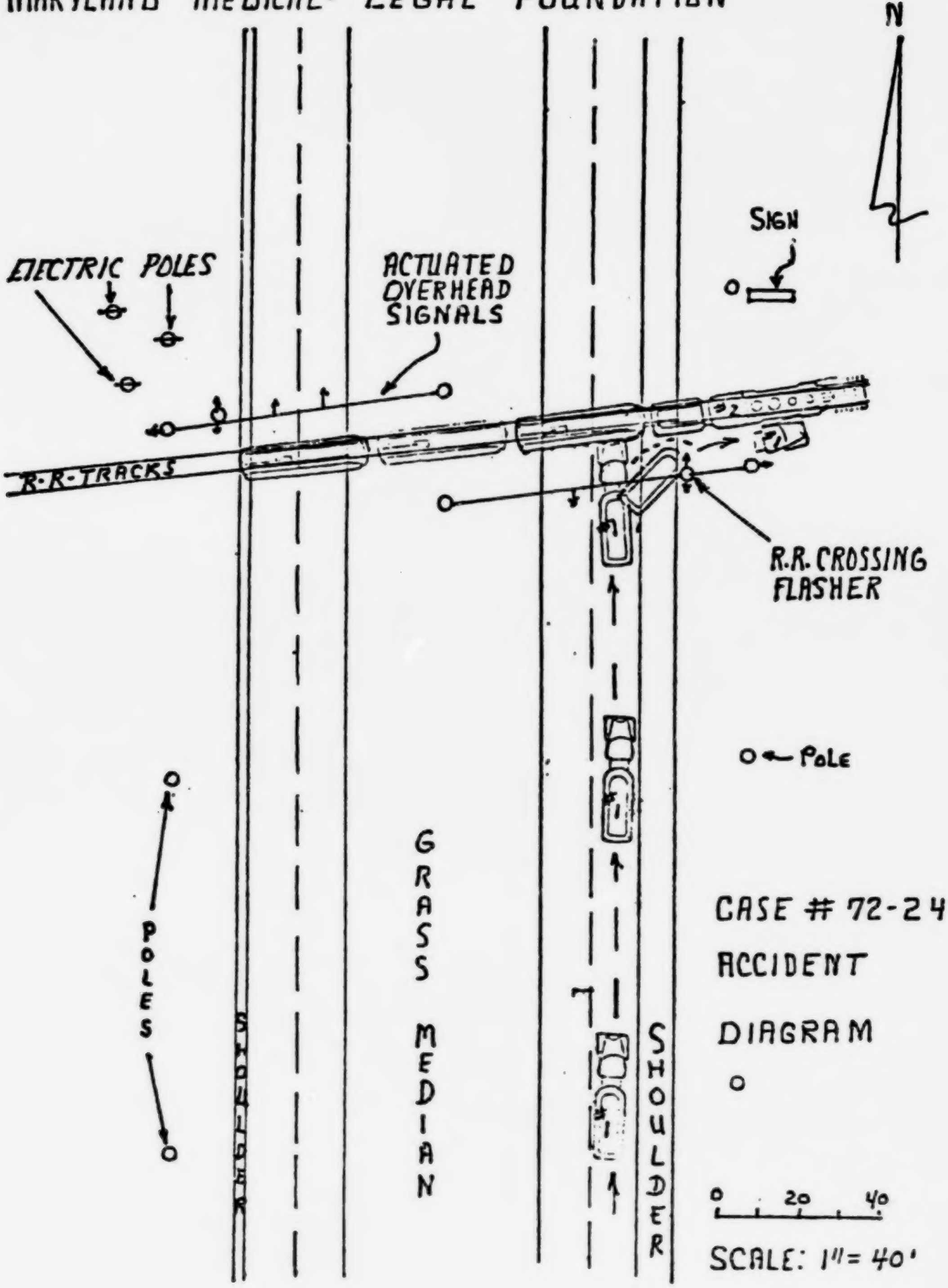
CASE # 72-24

CONDITION

DIAGRAM

SCALE: 1" = 40'

MARYLAND MEDICAL-LEGAL FOUNDATION


N
SIGN
ELECTRIC POLES
ACTUATED OVERHEAD SIGNALS
R-R-TRACKS
R.R. CROSSING FLASHER
O ← POLE
POLES
SHOULDER
GRASS MEDIAN
SHOULDER
0 20 40
SCALE: 1" = 40'

CASE # 72-24

ACCIDENT

DIAGRAM

ENCLOSURE F

Durham City Code
Durham, N.C.

Ch. 18 § 9 Locomotive Whistle.

It shall be unlawful for any person to blow or allow to be blown any locomotive whistle under his control within the city limits. (Code 1940, C. 28, § 8.)

Knoxville City Code
Knoxville, Tenn.

Ch. 33 § 8 Blowing Whistles.

It shall be unlawful for any person operating or in charge of a locomotive engine within the corporate limits of the city to blow the whistle on the same except as may be absolutely necessary in the use of the signals as laid down by the rules and regulations of railway companies, or as required by the laws of the state. (10-21-04.)

Houston City Code
Houston, Texas

Sec. 1843 Blowing Whistles; Blowing out Boiler

All persons are prohibited from blowing any whistles on any locomotive, or single blasts therefrom, within the limits of the city, for a longer period of time than five seconds, except when there is imminent danger of an accident. All persons are prohibited from blowing off or blowing out a boiler when crossing any public street or other thoroughfare within the limits of the city. Each and every person violating any provision of this section shall be fined in any sum, upon conviction, not less than five dollars and not exceeding fifty dollars.

Mason City, Iowa

26-29 Sounding of Locomotive Whistles

It shall be unlawful for any person to cause or permit any locomotive whistle to be sounded within the limits of the City except for the purpose of making necessary signals required by law or required for the safe operation of the railway, and where requisite signals cannot be made by other means. (R '16, Sec. 545.)

Chicago, Illinois

188-44. No person owning or operating a railroad shall cause or allow the whistle of any locomotive engine to be sounded within the city, except necessary brake signals and such as may be absolutely necessary to prevent injury to life and property.

Each locomotive engine shall be equipped with a bell-ringing device which shall at all times be maintained in repair and which shall cause the bell of the engine to be rung automatically. The bell of each locomotive engine shall be rung continuously while such locomotive is running within the city, excepting bells on locomotives running upon those railroad tracks enclosed by walls or fences, or enclosed by a wall on one side and public waters on the other side, and excepting bells on locomotives running upon those portions of the railroad track which have been elevated. In the case of these exceptions, no bell shall be rung or whistle blown except as signals of danger.

Buffalo, New York

Chapter V. RAILROADS

#4. It shall not be lawful for any person in the employ of any railroad company operating within the limits of the city to permit the whistle of the locomotive under his control to be blown, except for necessary signal purposes. Any person violating the provisions of this section shall pay a penalty of $25.00 for such offense.

NOTE: This restriction is generally associated with a train speed restriction of 6 MPH and the use of flagmen.

Lynchburg, Virginia

CITY CODE SUPPLEMENT (Railroad)

Sec. 3809. Sounding whistles or horns.

The sounding or blowing of locomotive whistles or horns within the corporate limits of the city of Lynchburg is hereby prohibited, except as may be necessary for the transmission of signals or in emergency to prevent accidents.

The provisions of this section shall not apply to the two crossings of the tracks of the Chesapeake and Ohio Railway

Company at Reusens, in the vicinity of the E. J. Lavino Company, because of the lack of sight distance and warning devices at these crossings.

Any violation of this ordinance shall be punished by a fine of not less than five dollars nor more than ten dollars for each offense. (1931, §704; 6-8-42; 8=28-56; 10-9-56)

State of Illinois

Under authority delegated to it by the State Legislature (114-59), the Illinois Commerce Commission adopted General Order #176 on August 15, 1957, excusing the sounding of horns and whistles at crossings protected by flashing lights. **This has now been incorporated in General Order No. 138, Revised, August 22, 1973, Rule 501.**

State of Florida

§351.03 limits signals to bells only in incorporated areas, with an accompanying speed limit of 12 mph.

ENCLOSURE G

COMMISSIONERS
VERNON L. STURGEON, PRESIDENT
WILLIAM SYMONS, JR.
J. P. VUKASIN, JR.
THOMAS MORAN
D. W. HOLMES

ADDRESS ALL COMMUNICATIONS
TO THE COMMISSION
CALIFORNIA STATE BUILDING
SAN FRANCISCO, CALIFORNIA 94102
TELEPHONE: (415) 557-1945

Public Utilities Commission
STATE OF CALIFORNIA

FILE NO. IC 79403

November 10, 1972

NOV 1 [illegible]

NOV 13 1972

Honorable Arlen Gregorio
The State Senate
12th District, San Mateo County
State Capitol
Sacramento, CA 95814

Dear Senator Gregorio:

Subsequent to receipt of your letter of October 4, 1972, our representative has discussed the use of train whistles approaching railroad grade crossings with Mr. John Gilroy and Ms. Charlotte Schultz of your staff.

As discussed with them, it may be necessary to sound the train whistle even at crossings equipped with automatic gates for the following reasons:

1. Possibility of a malfunction of the automatic grade crossing protection due to being struck by vehicles, vandalism or failure of track circuitry or signal apparatus.
2. Rail highway crossings are frequently traversed by bicyclists and pedestrians after the protective devices have been actuated by an approaching train.
3. Impatient motorists sometimes ignore crossing signals and have been known to drive around protective gate arms in an attempt to avoid being delayed by a train.
4. Liability on the part of the railroads for failure to use every means available to avoid an accident.

In view of the above, the staff feels that in the interest of safety, the railroads should not be prohibited from using the train whistles to warn persons that a train is approaching.

Yours very truly,

PUBLIC UTILITIES COMMISSION

By William R. Johnson

WILLIAM R. JOHNSON, Secretary

OPERATING RAILROAD RETARDER YARDS IN THE UNITED STATES

(CLASS I Railroads)

State	Yard	Railroad	Number of Tracks
Alabama	Birmingham	L&N	40
	Birmingham	Sou	56
	Sheffield	Sou	32
Arkansas	N. Little Rock	M. P.	64
	Pine Bluff	St. L. S. W.	30
California	City of Industry	S. P.	12
	East Los Angeles	U. P.	16
	Los Angeles	S. P.	40
	Richmond	S. P.	8
	Roseville	S. P.	49
	West Colton	S. P.	56
Colorado	Grand Jct.	D&RGW	31
	Pueblo	AT&SF	16
Connecticut	Cedar Hill (East)	P. C.	45
	Cedar Hill (West)	P. C.	38
Florida	Tampa	S. C. L.	8
Georgia	Atlanta	Sou	12
	Atlanta	Sou	65
	Atlanta	L&N	24
	Macon	Sou	50
Idaho	Pocatello	U. P.	40

State	Yard	Railroad	Number of Tracks
Illinois	Bensenville	C.M.S.P.&P.	70
	Blue Island	I. H. B.	42
	Chicago, Clearing (East)	B. R. Chgo	44
	Chicago, Clearing (West)	B. R. Chgo	36
	Chicago, Cicero	B. N.	43
	Chicago, Corwith	AT&SF	32
	Chicago, 59th St.	P. C.	42
	E. St. Louis	A. & S.	42
	E. St. Louis	I. C. G.	26
	Galesburg (East)	B. N.	49
	Galesburg (West)	B. N.	35
	Madison	T. R. R. A.	34
	Markam	I. C. G.	64
	Markam	I. C. G.	45
	Proviso	C. N. W.	59
	Silvio	C. R. I. P.	50
Indiana	Elkhart	P. C.	72
	Gary	E. J. & E.	58
	Gibson (South)	I. H. B.	30
	Gibson (North)	I. H. B.	30
	Indianapolis	P. C.	64
Kansas	Argentine (East)	AT&SF	48
	Argentine (West)	AT&SF	56
	Armourdale	C. R. I. P.	40
Kentucky	DeCoursey (North)	L&N	20
	DeCoursey (South)	L&N	24
	Russell	C&O/B&O	32
	Stevens	C&O/B&O	15
Louisiana	Geismer	I. C. G.	6
Maryland	Cumberland (West)	C&O/B&O	32
	Cumberland (East)	C&O/B&O	16
Massachusetts	Boston	B&M	22

State	Yard	Railroad	Number of Tracks
Michigan	Detroit	DT&I	36
	West Detroit	P. C.	31
Minnesota	Minneapolis	B. N.	63
	St. Paul	C.M.S.P.&P.	40
Missouri	Kansas City (East)	M. P.	42
	Kansas City (West)	M. P.	32
	N. Kansas City	B. N.	42
Montana	Missoula	B. N.	9
Nebraska	Lincoln	B. N.	36
	N. Platte	U. P.	62
	N. Platte (West)	U. P.	42
New Jersey	Morrisville	P. C.	38
	Pavonia	P. C.	32
New York	Buffalo	E. L.	56
	Buffalo	P. C.	63
	DeWitt	P. C.	27
	Mechanicville	B&M	36
North Carolina	Hamlet	S. C. L.	58
North Dakota	Minot	B. N.	40
Ohio	Bellevue	N&W	42
	Columbus	P. C.	40
	Grandview	P. C.	9
	Marion	E. L.	24
	Portsmouth	N&W	18
	Portsmouth (West)	N&W	35
	Sharonville	P. C.	35
	Stanley	P. C.	42
	Walkridge	C&O/B&O	68
	Willard	C&O/B&O	52
Oklahoma	Tulsa	S. L. S. F.	40

State	Yard	Railroad	Number of Tracks
Oregon	Eugene	S. P.	32
Pennsylvania	Allentown	CNJ/LV	19
	Connellsville	C&O/B&O	15
	Conway (East)	P. C.	54
	Conway (West)	P. C.	56
	Enola (East)	P. C.	33
	Enola (West)	P. C.	36
	Pittsburgh	U. R. R.	23
	Pittsburgh	Mon-Conn.	22
	Rutherford (East)	Reading	33
	Rutherford (West)	Reading	18
Tennessee	Chattanooga	Sou	50
	Knoxville	Sou	46
	Memphis	S. L. S. F.	50
	Nashville	L&N	56
Texas	Beaumont	S. P.	12
	Fort Worth	M. P./T. P.	44
	Houston	S. P.	48
Virginia	Alexandria (North)	R. F. P.	49
	Alexandria (South)	R. F. P.	39
	Bluefield	N&W	13
	Lamperts Point (empty)	N&W	36
	Lamperts Point (loaded)	N&W	36
	Lamperts Point	N&W	30
	Newport News	C&O/B&O	15
	Roanoke	N&W	56
Washington	Pasco	B. N.	47
	Seattle	B. N.	16

State	Yard	Railroad	Number of Tracks
Wisconsin	Milwaukee	C.M.S.P.&P.	35

Abbreviations of Railroad Names Used in this Table*

L&N – Louisville and Nashville
Sou – Southern
M.P. – Missouri Pacific
St. L.S.W. – St. Louis Southwestern
S.P. – Southern Pacific
U.P. – Union Pacific
D&RGW – Denver and Rio Grande Western
AT&SF – Atchison, Topeka and Santa Fe
P.C. – Penn Central
S.C.L. – Seaboard Coast Line
C.M.S.P.&P. – Chicago, Milwaukee, St. Paul and Pacific
I.H.B. – Indiana Harbor Belt Railway
B.R. Chgo – Belt Railway of Chicago
B.N. – Burlington Northern
I.C.G. – Illinois Central Gulf
A. & S. – Alton and Southern
T.R.R.A. – Terminal Railroad Assoc. of St. Louis
C.N.W. – Chicago and North Western
C.R.I.P. – Chicago, Rock Island and Pacific
E.J. & E. – Elgin, Joliet, and Eastern
C&O/B&O – Chesapeake and Ohio
Baltimore and Ohio
B&M – Boston and Maine
D.T.&I. – Detroit, Toldeo, and Ironton
E.L. – Erie Lackawanna
N&W – Norfolk and Western
S.L.S.F. – St. Louis San Francisco
CNJ/LV – Central Railroad of New Jersey
Lehigh Valley
U.R.R. – Union Railroad
Mon-Conn. – Monongahela Connecting
Reading – Reading Company
M.P./T.P. – Missouri Pacific/Texas Pacific
R.F.P. – Richmond, Fredericksburg and Potomac

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*These abbreviations reflect mergers; the abbreviations on the accompanying map frequently do not reflect mergers.

SUMMARY OF YARD NOISE IMPACT STUDY

INTRODUCTION

The rail yard modeling study of noise impact on people used data collected at the Cicero Yard of the Burlington Northern near Chicago Illinois. The study included the analysis of eight railroad yards from a population density and yard layout standpoint which led to the selection of the Cicero Yard for more detailed analysis. Characteristics of the noise emitted from the Cicero Yard under a range of operating conditions were studied and a model of the yard was developed. The model was then used to predict the impact on people (environmental noise levels) of various noise abatement activities on different aspects of the Cicero Yard operation.

CASE STUDIES OF RAILROAD YARDS

Eight yards having a wide range of characteristics were selected in order to compare yard traffic with population densities near them. Such a comparison provides a basis for determining the number and frequency of exposure of people to noise from railroad yards. Figures D.1 - D.8 are maps of the yards that were studied. Although no detailed studies of the zoning around the yards were attempted, the maps provide some indication of land use. The configuration of the yards and the traffic through the yards were determined by telephoning the yard superintendants or the yard masters. Table D.1 summarizes the population and traffic data for the yards.

The population information was taken from the *1970 Census of Housing, Block Statistics* for each city. The total populations for the cities studied were obtained from the *1970 Census of Population, U.S. Summary*. Population densities were derived for strips 250 or 500 ft wide for the entire length of the yards and/or for a total of 2000 ft from the retarders. Often, separate population density estimates were made for each side of a yard, since people are not evenly distributed around yards. Figures D.1 - D.8 contain graphs of the population distribution for each area.

The population of the cities in which the yards are located ranges from 67,058 (Cicero) to 1,800 (Roseville). Population cannot be considered an index of urbanization since all of the towns are in urbanized areas generally outside a larger urban city. No yard located in a "rural" area was studied as sufficiently detailed population statistics were not available for a yard located in other than urbanized areas.

STATISTICAL ANALYSIS OF NOISE NEAR RAILROAD YARDS

Many methods of describing community noise have been proposed, studied, and evaluated, but the most suitable method for describing environmental noise and its effect on people, in EPA's

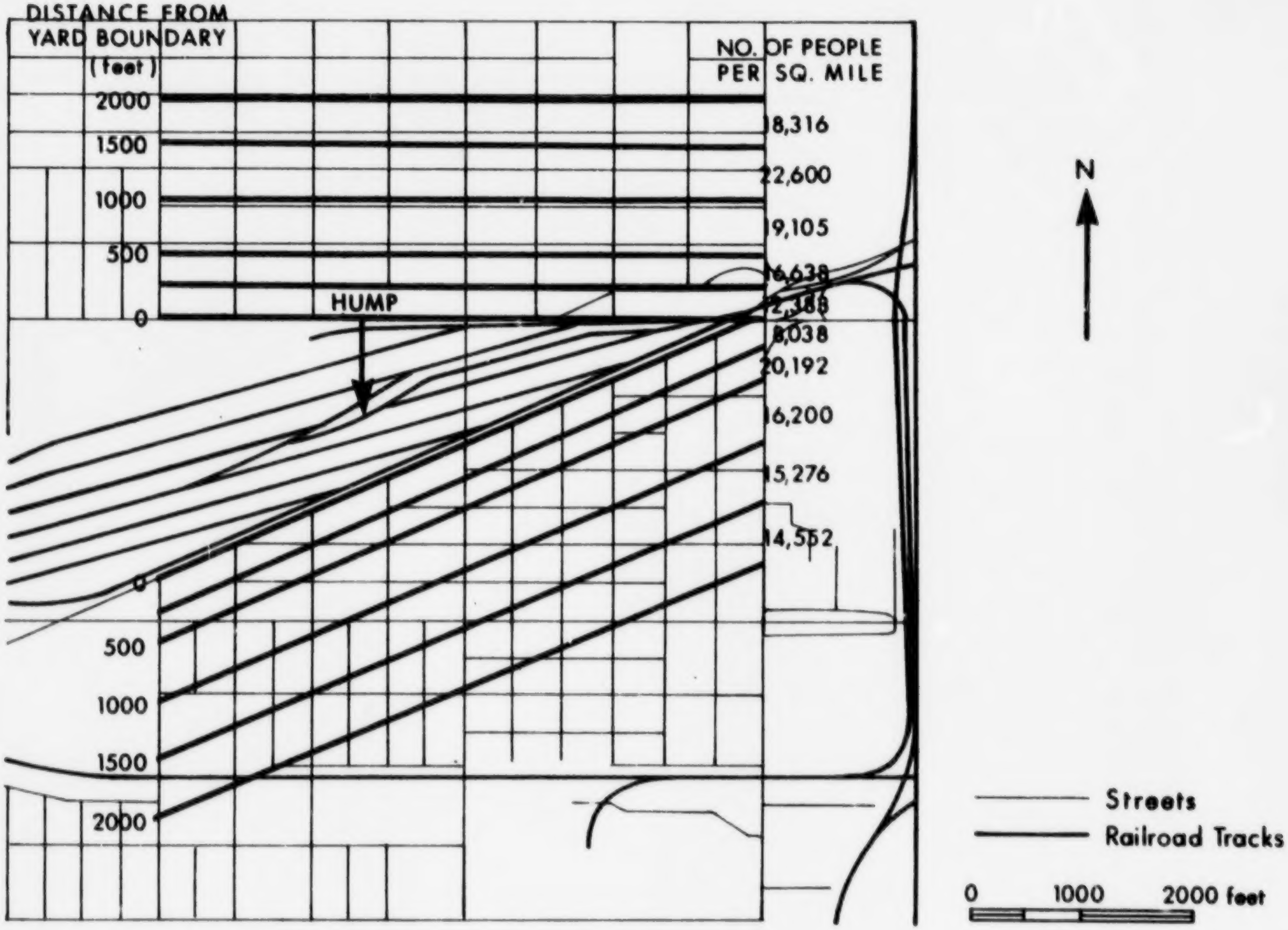
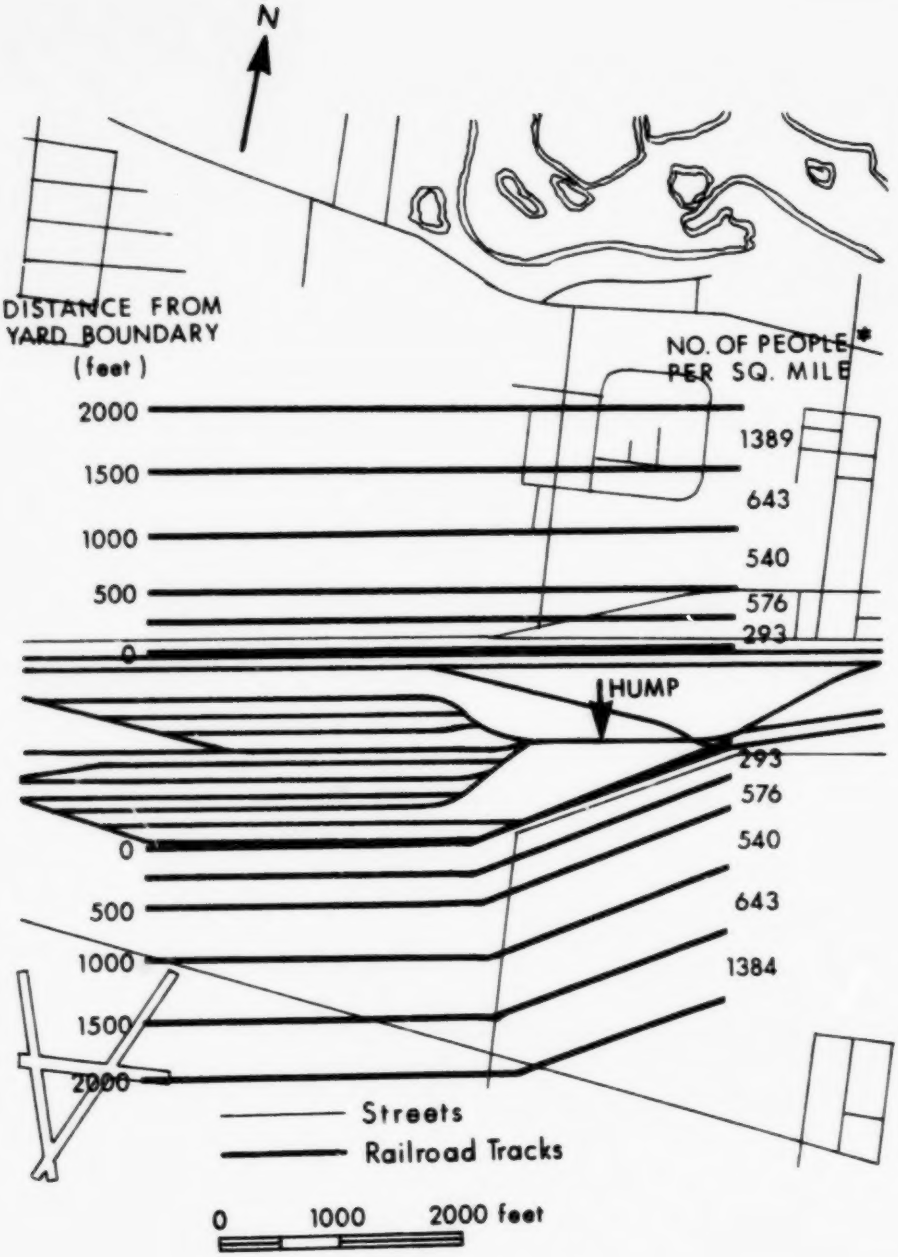

DISTANCE FROM YARD BOUNDARY (feet)
2000
1500
1000
500
0
HUMP
0
500
1000
1500
2000
NO. OF PEOPLE PER SQ. MILE
18,316
22,600
19,105
16,638
12,388
8,038
20,192
16,200
15,276
14,552
N
Streets
Railroad Tracks
0
1000
2000 feet

FIG D.1. MAP AND POPULATION DENSITY PROFILES FOR THE CICERO. ILLINOIS HUMP YARD.


N
DISTANCE FROM YARD BOUNDARY (feet)
NO. OF PEOPLE* PER SQ. MILE
2000
1500
1000
500
0
1389
643
540
576
293
HUMP
293
576
540
643
1384
0
500
1000
1500
2000
Streets
Railroad Tracks
0
1000
2000 feet

*Both Sides Averaged Together

FIG. D.2. MAP AND POPULATION DENSITY PROFILES FOR THE ELKHART, INDIANA HUMP YARD.

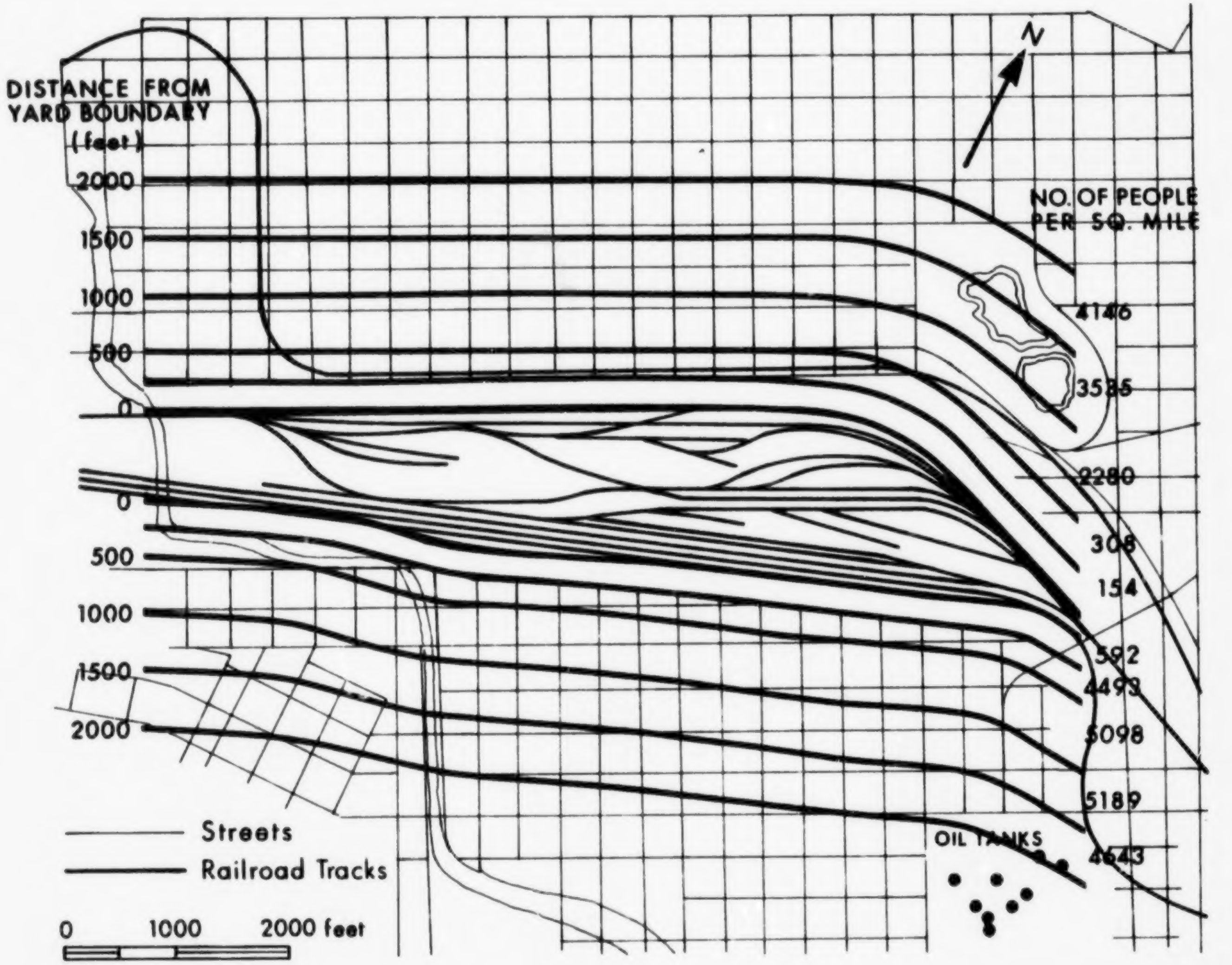

DISTANCE FROM YARD BOUNDARY (feet)
2000
1500
1000
500
0
0
500
1000
1500
2000
N
NO. OF PEOPLE PER SQ. MILE
4146
3535
2280
308
154
592
4493
5098
5189
4643
OIL TANKS
Streets
Railroad Tracks
0
1000
2000 feet

FIG. D.3. MAP AND POPULATION DENSITY PROFILES FOR THE CHEYENNE, WYOMING FLAT YARD.

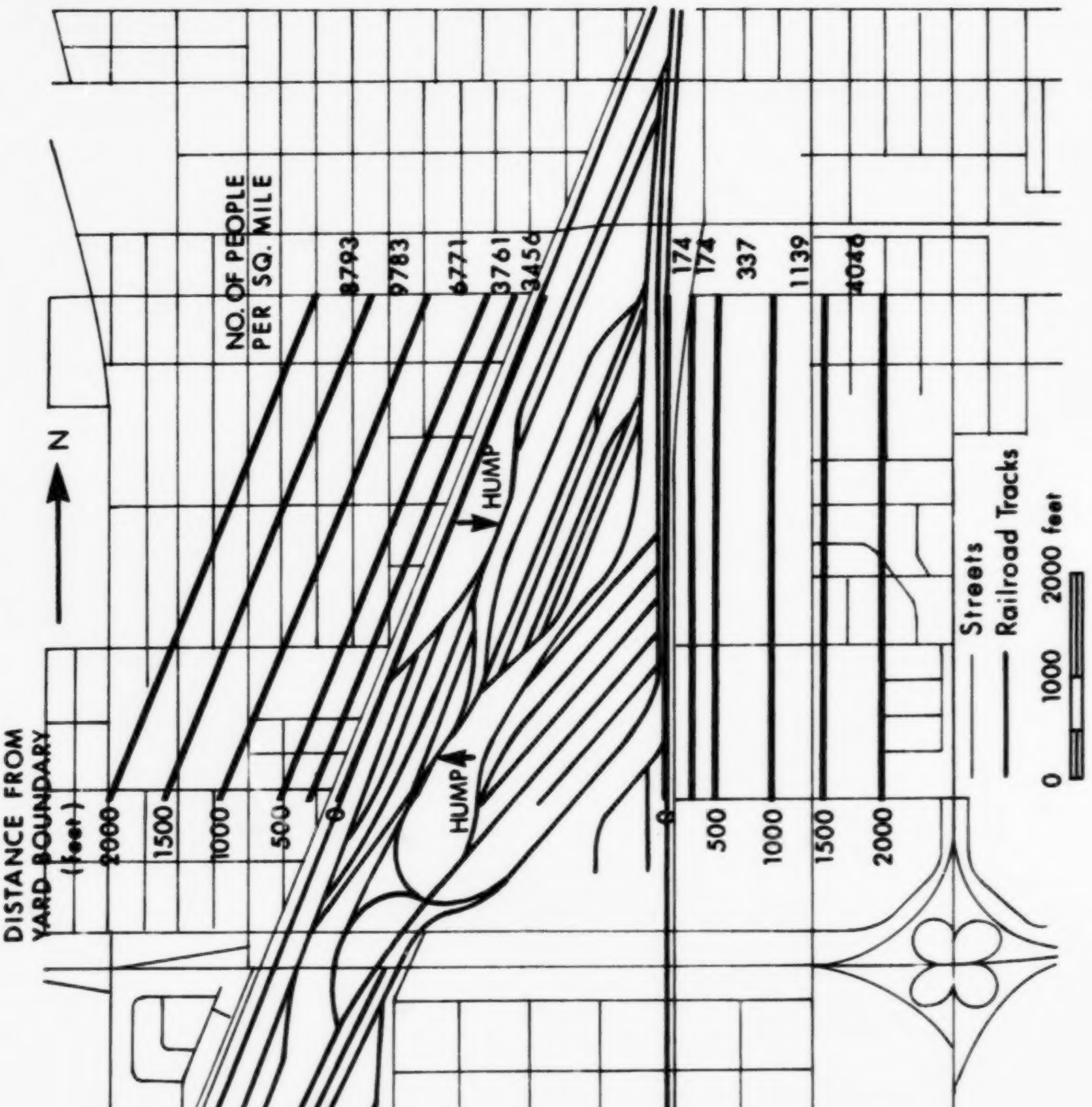

DISTANCE FROM YARD BOUNDARY (feet)
2000
1500
1000
500
0
NO. OF PEOPLE PER SQ. MILE
8793
9783
6771
3761
3456
174
174
337
1139
4046
N
HUMP
HUMP
0
500
1000
1500
2000
Streets
Railroad Tracks
0
1000
2000 feet

FIG. D.4. MAP AND POPULATION DENSITY PROFILES FOR THE MARKHAM, ILLINOIS HUMP YARD.

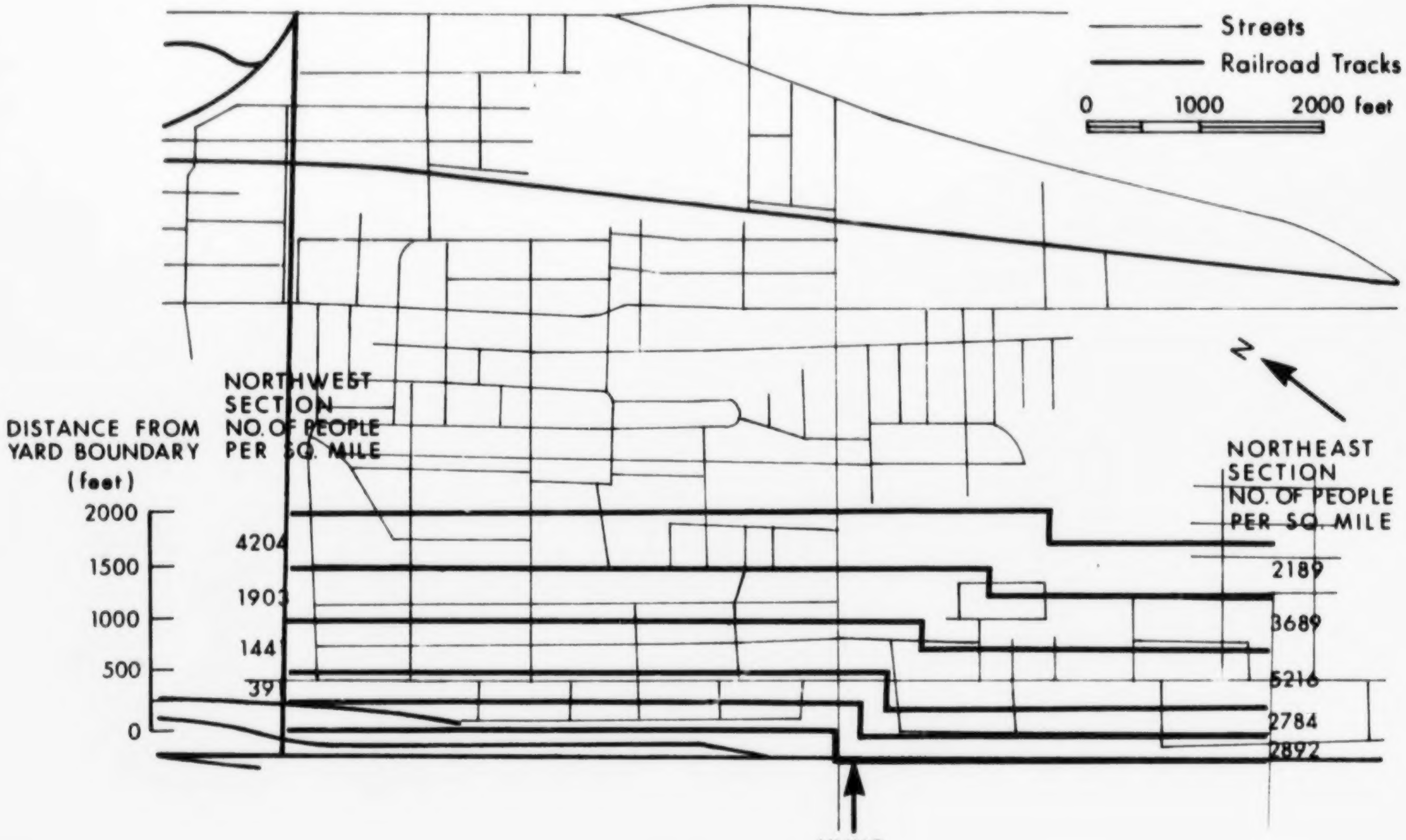

Streets
Railroad Tracks
0
1000
2000 feet
N
DISTANCE FROM YARD BOUNDARY (feet)
2000
1500
1000
500
0
NORTHWEST SECTION NO. OF PEOPLE PER SQ. MILE
4204
1903
144
39
NORTHEAST SECTION NO. OF PEOPLE PER SQ. MILE
2189
3689
5216
2784
2892
HUMP

Fig. D.5. MAP AND POPULATION DENSITY FOR THE CENTREVILLE, ILLINOIS HUMP YARD.

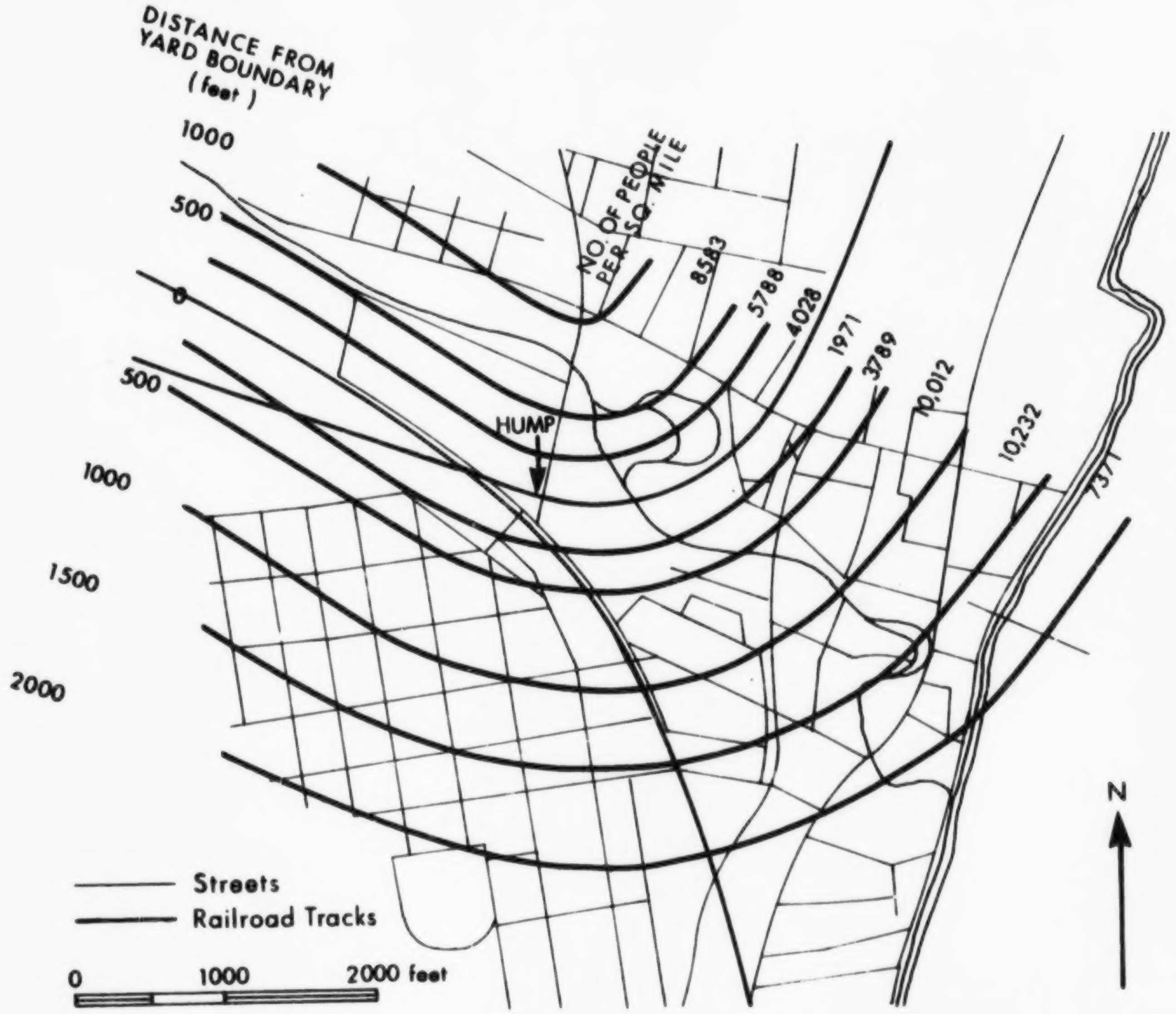

DISTANCE FROM YARD BOUNDARY (feet)
1000
500
0
500
1000
1500
2000
NO. OF PEOPLE PER SQ. MILE
8583
5788
4028
1971
3789
10,012
10,232
7371
HUMP
N
Streets
Railroad Tracks
0
1000
2000 feet

FIG. D.6. MAP AND POPULATION DENSITY PROFILES FOR THE MECHANICVILLE, NEW YORK HUMP YARD.

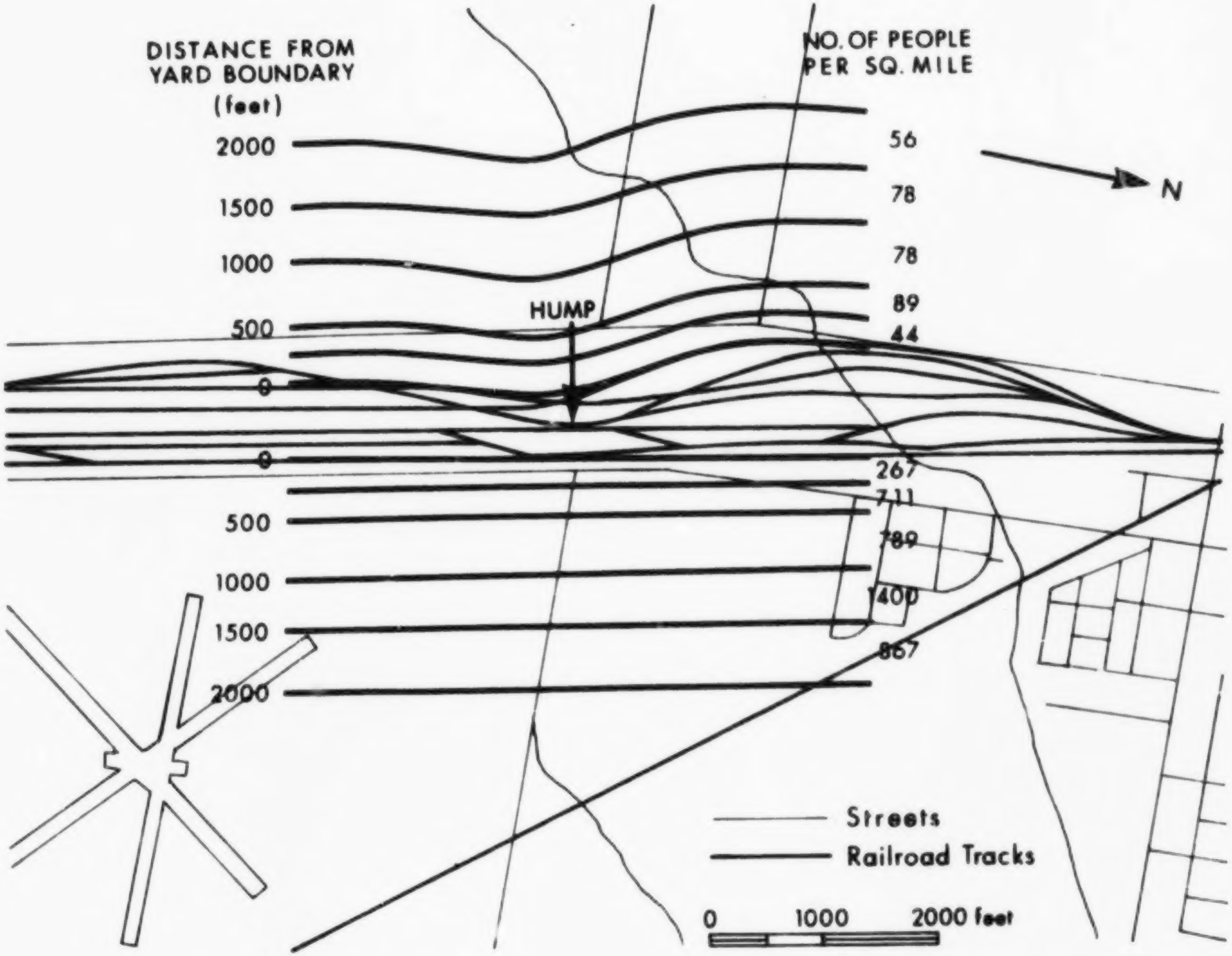

DISTANCE FROM YARD BOUNDARY (feet)
2000
1500
1000
500
0
0
500
1000
1500
2000
HUMP
NO. OF PEOPLE PER SQ. MILE
56
78
78
89
44
267
711
789
1400
867
N
Streets
Railroad Tracks
0
1000
2000 feet

FIG. D.7. MAP AND POPULATION DENSITY PROFILES FOR THE WALBRIDGE, OHIO HUMP YARD.

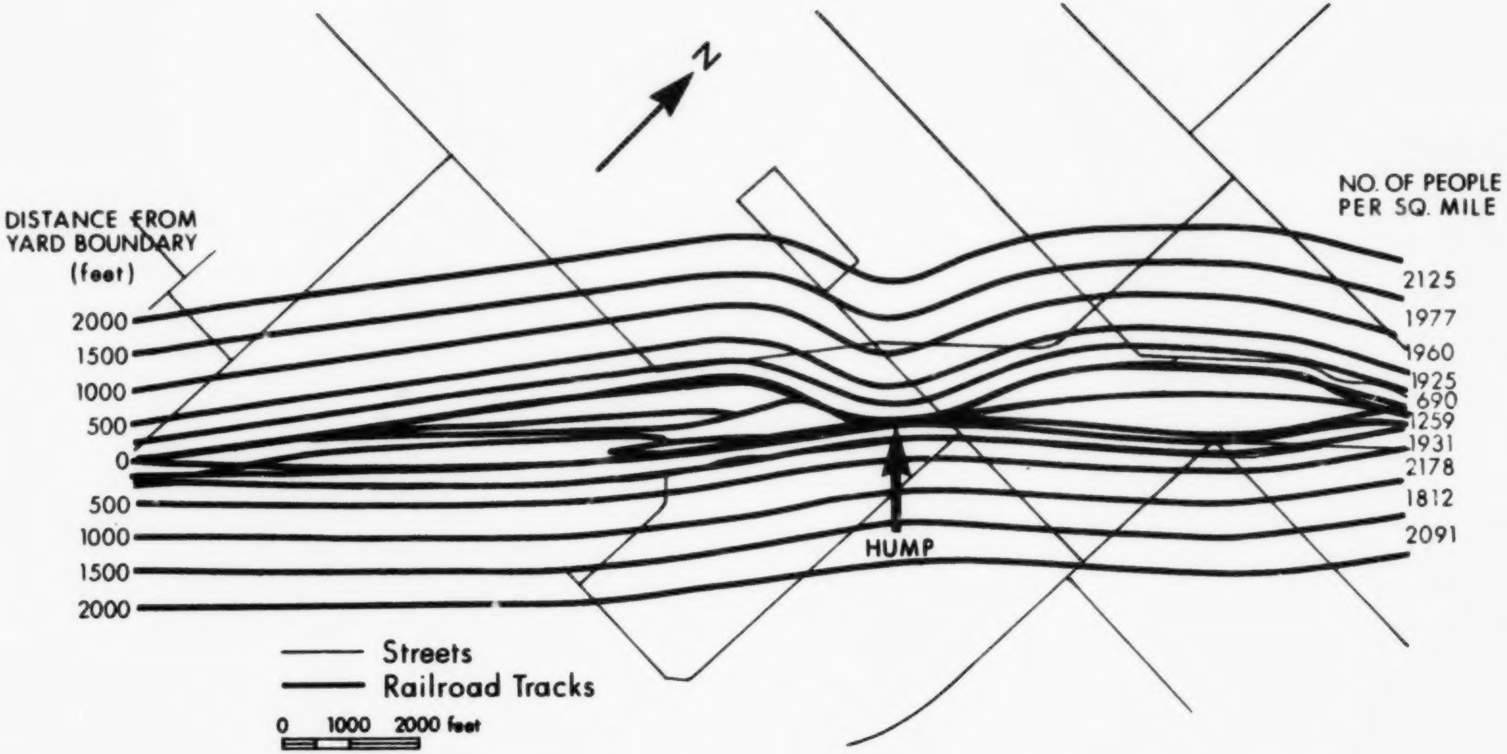

DISTANCE FROM
YARD BOUNDARY
(feet)
2000
1500
1000
500
0
500
1000
1500
2000
NO. OF PEOPLE
PER SQ. MILE
2125
1977
1960
1925
690
1259
1931
2178
1812
2091
N
HUMP
Streets
Railroad Tracks
0
1000
2000 feet

FIG. D.8. MAP AND POPULATION DENSITY PROFILES FOR THE ROSEVILLE, CALIFORNIA HUMP YARD.

TABLE D-1 POPULATION DENSITY AND RAILROAD CAR TRAFFIC FOR VARIOUS RAILROAD YARDS

City and State Yard Operator	Total Population	No. of Cars Per Day	No. of People Per Square Mile Within:					Comments	
			0-250'	250'-500'	500'-1000'	1000'-1500'	1500'-2000'		
Cicero, Ill Burlington North.	67,058	1000	12,383	16,638	19,105	22,600	18,316	North Section	43 tracks one master & 6 group retarders
			8,038	20,192	16,200	15,276	14,552	South Section	
Elkhart, Ind. Penn. Central	43,152	6800	293	576	540	643	1,384		72 tracks 1200 cars/day bypass retarder; manual release inert retarders Airport nearby
Cheyenne, Wyo. Union Pacific	40,152	4000	592	4,493	5,098	5,189	4,643	South Section	Flat yard; locomotives work entire length of the yard
			154	308	2,280	3,535	4,146	North Section	
Markham, Ill. Ill.,Central & Gulf	15,987	3200-3400	174	174	337	1,139	4,046	East Section	45 tracks two masters, 6 intermediate, 15 group retarders; 400 cars/day bypass retarder, no inert retarders
			3,456	3,761	6,771	9,783	8,793	West Section	
Centreville, Ill. Ill.,Central & Gulf	11,978	3300-4000	2,892	2,784	5,216	3,689	2,189	Northeast Section	30 tracks one master, 3 group retarders 1200 cars/day through retarders manual or automatic release inerts
				391	1,411	1,903	4,204	Northwest Section	
Mechanicville, N.Y. Boston & Maine	6,247	800	1,971	3,789	10,012	10,232	7,371	South Section	one master & 6 group retarders 36 tracks, 19 in use; 19 inert retarders
			4,028	5,788	8,583			North Section	
Walbridge, Ohio Baltimore & Ohio	3,028	1500	44	89	78	78	56	Western Section	68 tracks one master & 8 group retarders; no inert retarders Airport nearby
			267	711	789	1,400	867	Eastern Section	
Roseville, Calif. Southern Pacific	17,895	6500	1,259	1,931	2,178	1,812	2,091	Southeast Section (entire yard)	49 tracks two humps, two master retarders 7 group retarders 49 spring-loaded inert retarders
			690	1,925	1,960	1,977	2,125	Northwest Section (entire yard)	
			170	319	263	642	389	Southeast Section (opposite retarders)	
			1,276	2,468	3,947	4,053	2,516	Northwest Section (opposite retarders)	

judgment, is the day/night sound level (re: Levels Document). L_{dn} may be obtained from an analysis of statittical records of noise (Schultz, 1972). Details of this procedure are in enclosure A of section 8 of this document. "Time records" usually means magnetic tape recordings made at the measurement site with rugged, portable, high-quality tape recorders. Permanent recordings permit processing a given noise record in several different ways, freeing the investigator from the restrictions imposed by the particular analysis that might be suitable in the field.

Figure D.9 shows portions of a time history of noise measured around 5:00 a.m. near residences about 400 ft from the boundary of a railroad yard. The record from which Figure D.9 was constructed was produced by playing a magnetic tape recording of the noise through an A-weighting network into a graphic level recorder. The figures show some significant noise events that are not associated with railroad operations. Those events must be iliminated from statistical analysis of the information on the tapes if the results are to be descriptive of railroad noise only.

An edited tape, from which all non-railroad noises were removed, was prepared by selectively interrupting a re-recording of the original tape. Both the unedited and the edited tapes of railroad noise were processed using an electronic statistical analyzer and a digital computer, to produce statistical analyses like the one shown in Figure D.10a. The tape which was generated is shown in Figure D.9. Figure D.10b shows the result of a statistical analysis of the edited version of the tape that generated Figure D.10a. The solid lines in Figure D.10b represent the data from Figure D.10a.

Figure D.10b shows that editing out extraneous events did not cause large changes in the statistical properties of the recorded noise, and the effect is typical of cases for which editing was possible. For times when the community was active, it was impossible to discriminate between noises due to railroad operations and other noises.

Figure D.11 shows the results of a statistical analysis of an edited tape recording of noises at the boundary of a busy yard. Even though a few diesel trucks traveled along a street adjacent to the boundary, editing the recorded sounds produced negligible changes in their statistical properties.

Figures D.12a and D.12b demonstrate a contrasting situation. Figure D.12a shows the results of statistical analysis of an unedited tape recording of noises at the boundary of the yard described above during a period of relative inactivity. Since much of the noise in the vicinity was extraneous (mostly diesel trucks), editing changed the statistical properties of the recorded noise. Figure D.12b shows the effect of editing this tape. Even though there were few readily noticeable railroad noises during the period covered by Figure D.12, the continuous background noise is higher at the boundary of the yard than in the community, illustrating the contributions of continuously idling locomotives and other noises associated with the activities of men and machines assigned to the yard.

"Energy Mean Level" is one of the parameters shown in the computer listings in Figures D.10 through D.12. That parameter, usually called "L_{EQ}" is the level of the continuous sound that

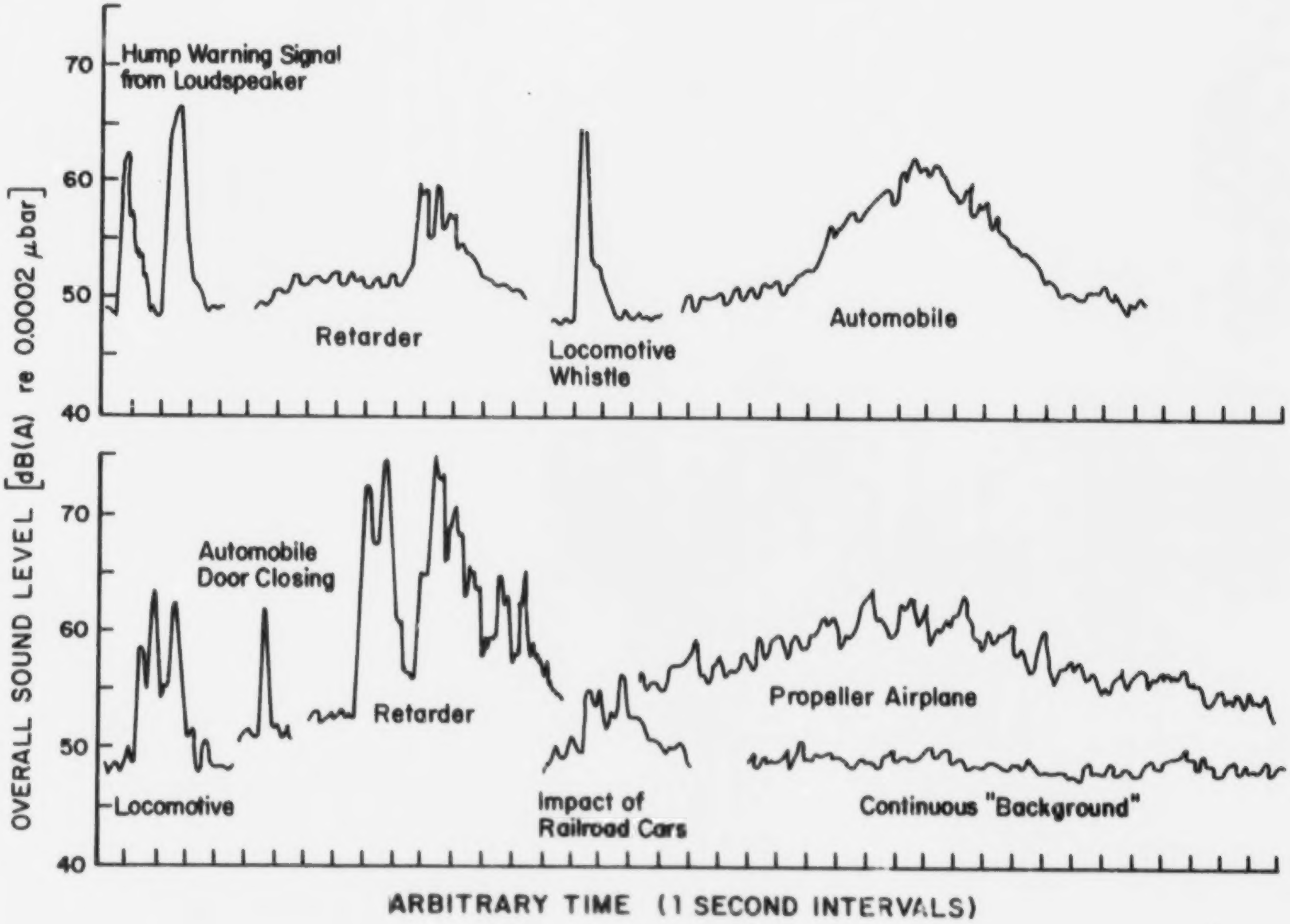
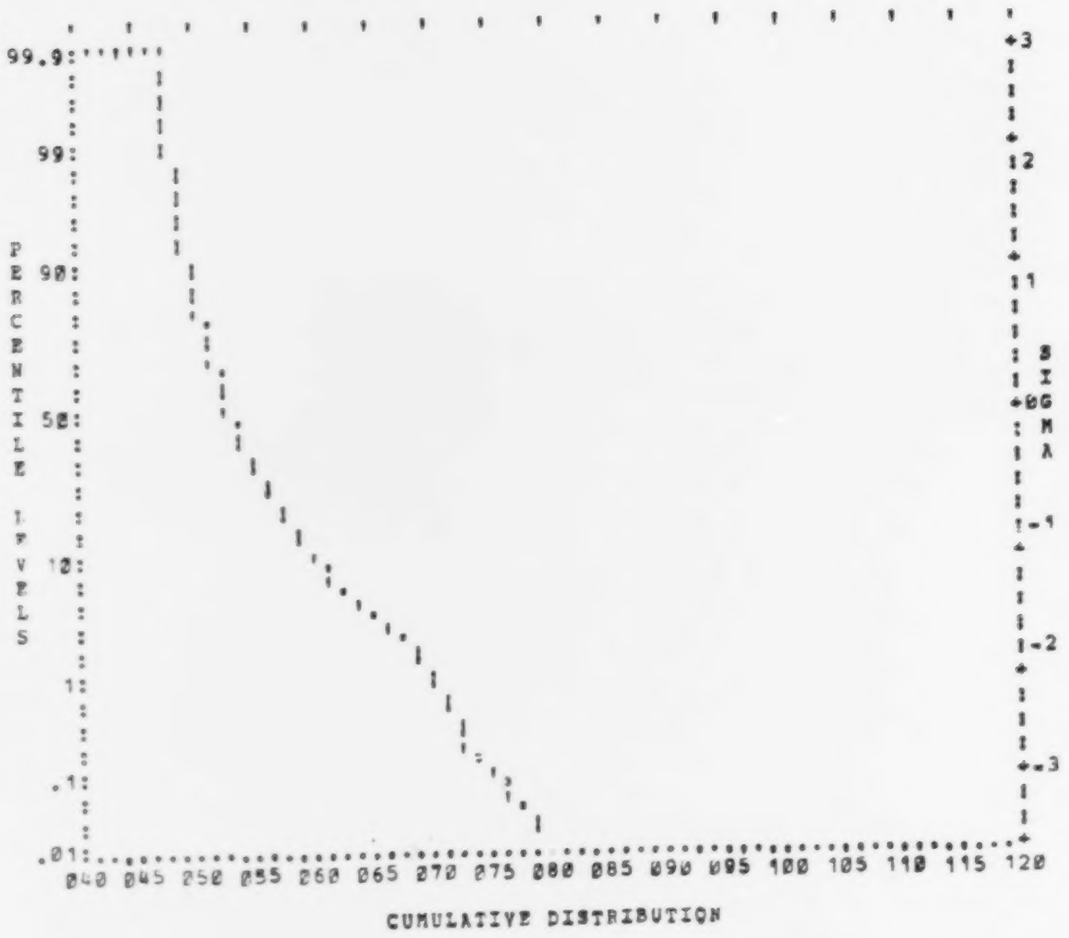


FIG. D.9. SELECTED EVENTS FROM A TIME HISTORY OF NOISE IN A COMMUNITY 400 FT FROM THE BOUNDARY OF A RAILROAD HUMP YARD.

```
GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA

CICERO YARD, MAY 17,1973, 5:20 A.M., WEST 30TH ST,
```

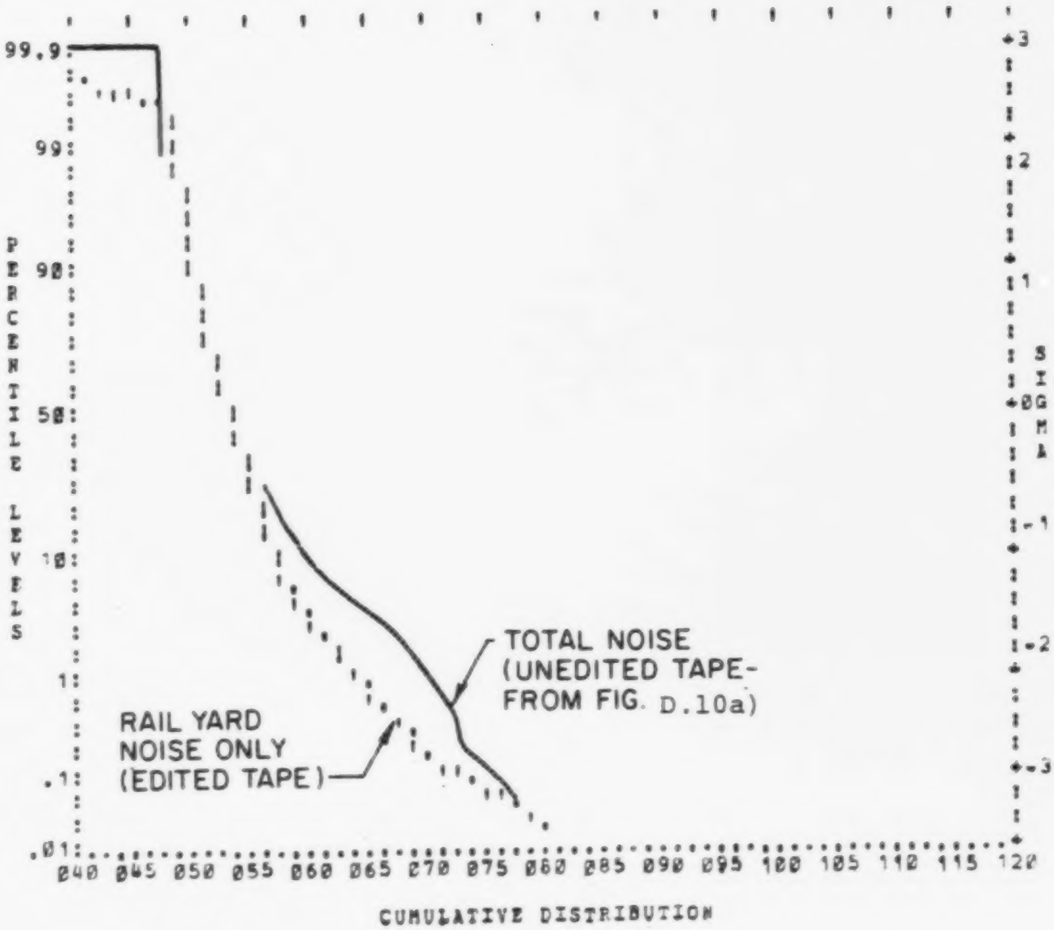


```
MAXIMUM NOISE LEVEL     =  82,5
MINIMUM NOISE LEVEL     =  31,3
NOISE POLLUTION LEVEL =  71,1
STANDARD DEVIATION      =   4,9
ENERGY MEAN LEVEL       =  58,6
```

FIG. D.10a. STATISTICS OF NOISE IN A COMMUNITY 400 FT FROM THE BOUNDARY OF A RAILROAD YARD (TOTAL NOISE; UNEDITED TAPE).

```
GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA

CICERO YARD, MAY 17,1973, 5:20 A.M., WEST 30TH ST.
(EDITED)
```

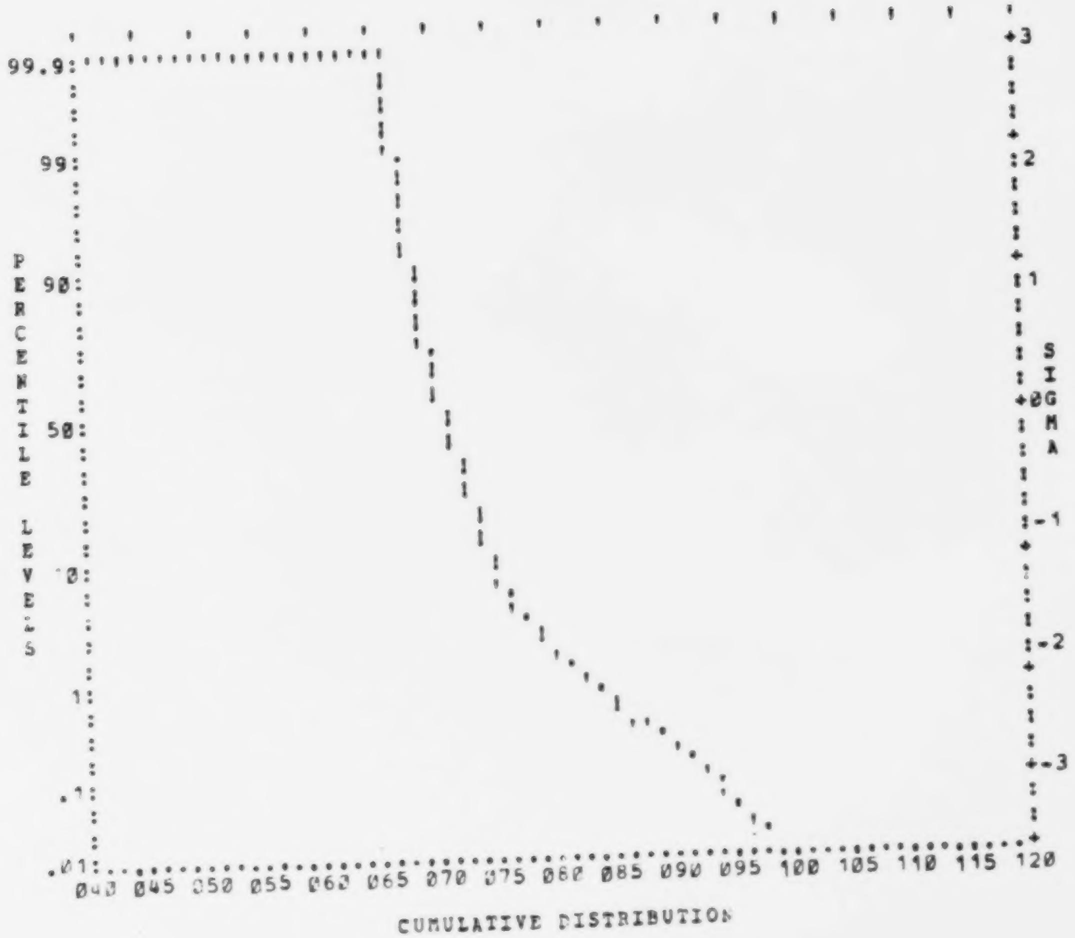


```
MAXIMUM NOISE LEVEL   =  80.0
MINIMUM NOISE LEVEL   =  31.3
NOISE POLLUTION LEVEL =  64.3
STANDARD DEVIATION    =   3.3
ENERGY MEAN LEVEL     =  55.8
```

FIG. D.10b. STATISTICS OF NOISE IN A COMMUNITY 400 FT FROM THE BOUNDARY OF A RAILROAD YARD (COMPARISON OF EDITED AND UNEDITED TAPES).

```
GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA


CICERO YARD, MAY 17,1973, 5:18 A.M., OGDEN AVE.
(EDITED)
```

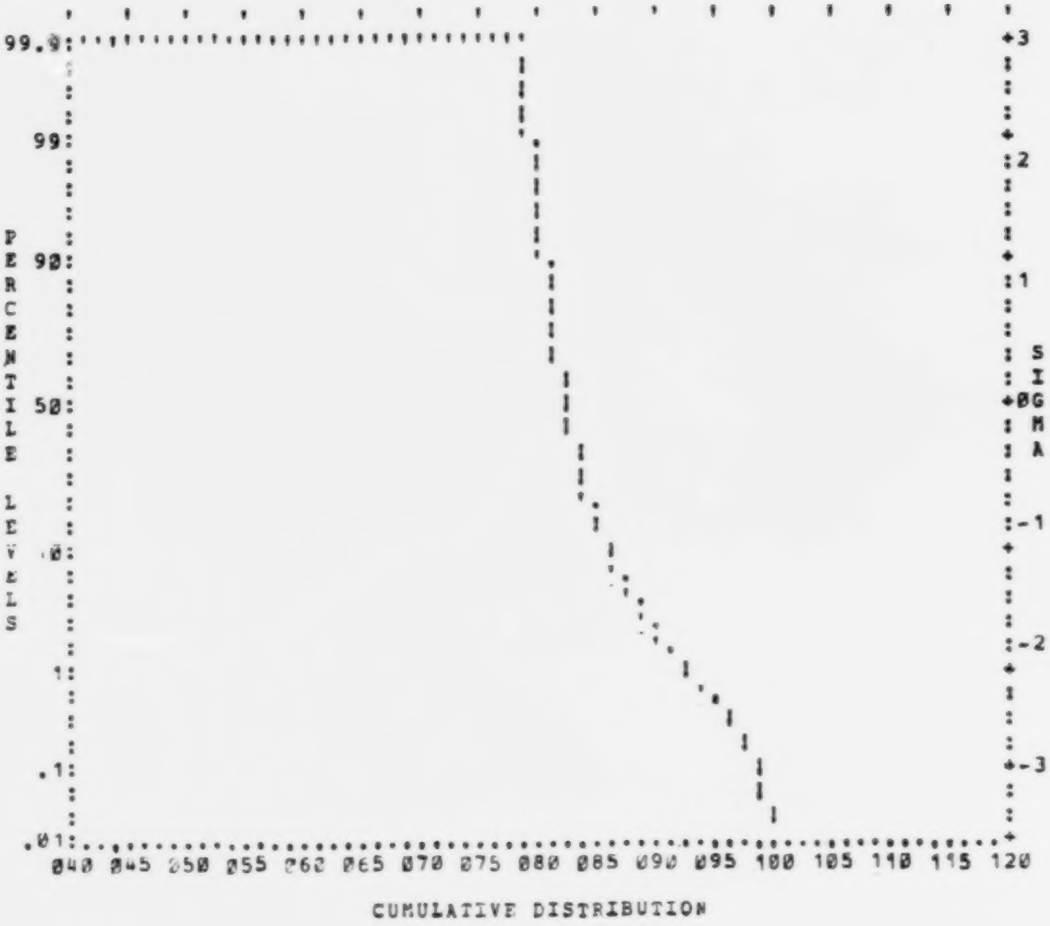


```
MAXIMUM NOISE LEVEL    =  97.5
MINIMUM NOISE LEVEL    =  65.0
NOISE POLLUTION LEVEL  =  82.6
STANDARD DEVIATION     =   3.3
ENERGY MEAN LEVEL      =  74.0
```

FIG. D.11. STATISTICS OF NOISE AT THE BOUNDARY OF A RAILROAD YARD WHILE THE YARD WAS BUSY (RAILROAD NOISE ONLY; EDITED TAPE).

```
GRAPHICAL OUTPUT  F STATISTICAL NOISE DATA


CICERO YARD, MAY 17,1973, 3:30 A.M., OGDEN AVE.
```

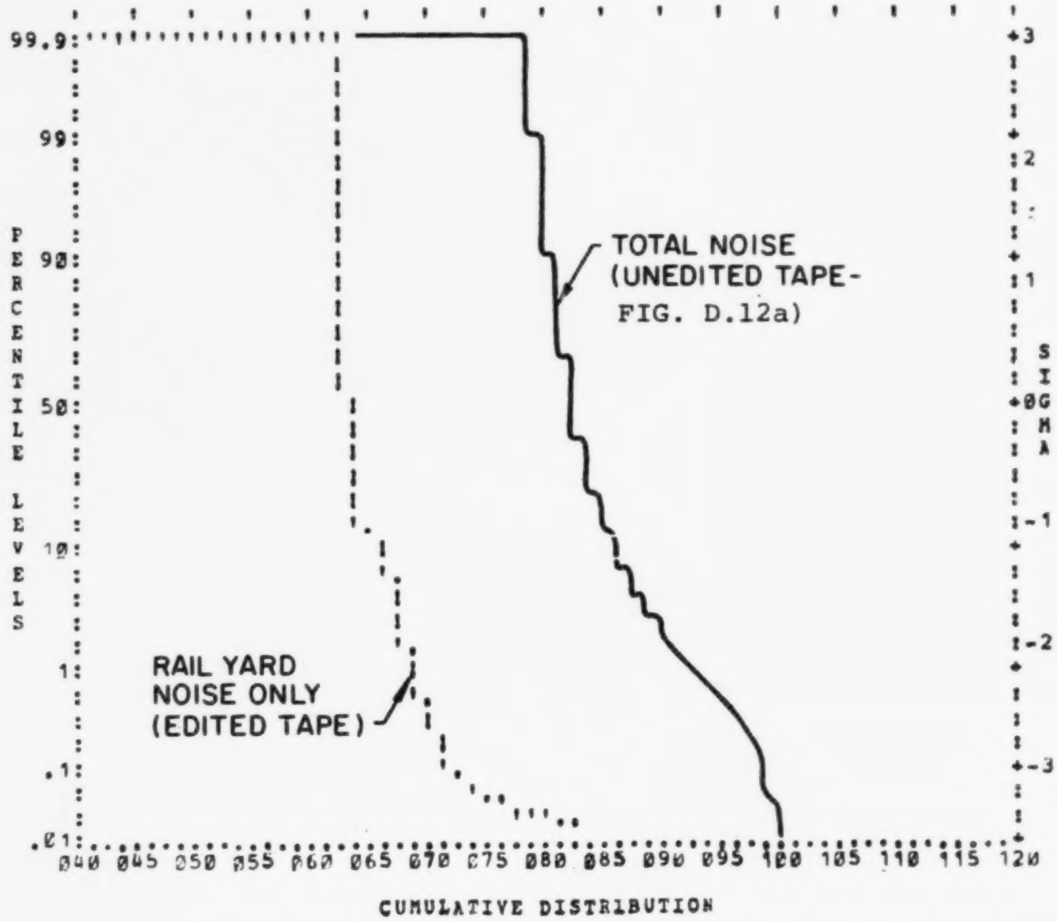


```
MAXIMUM NOISE LEVEL    =  98,8
MINIMUM NOISE LEVEL    =  77,5
NOISE POLLUTION LEVEL  =  90,7
STANDARD DEVIATION     =   2,7
ENERGY MEAN LEVEL      =  83,9
```

FIG. D.12a. STATISTICS OF NOISE AT THE BOUNDARY OF A RAILROAD YARD WHILE THE YARD WAS QUIET (TOTAL NOISE; UNEDITED TAPE).

```
GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA


CICERO YARD, MAY 17,1973, 3:30 A.M., OGDEN AVE,
(EDITED)
```



```
MAXIMUM NOISE LEVEL    =  93.8
MINIMUM NOISE LEVEL    =  62.5
NOISE POLLUTION LEVEL  =  68.0
STANDARD DEVIATION     =   1.6
ENERGY MEAN LEVEL      =  64.0
PERCENTILE LEVELS;L1   =  69.1
                L4.2   =  67.4
                 L10   =  66.5
               L33.3   =  63.5
                 L50   =  63.3
                 L90   =  62.7
                 L99   =  62.5
TRAFFIC NOISE INDEX    =  47.9
```

FIG. D.12b. STATISTICS OF NOISE AT THE BOUNDARY OF A RAILROAD YARD WHILE THE YARD WAS QUIET (COMPARISON OF EDITED AND UNEDITED TAPES).

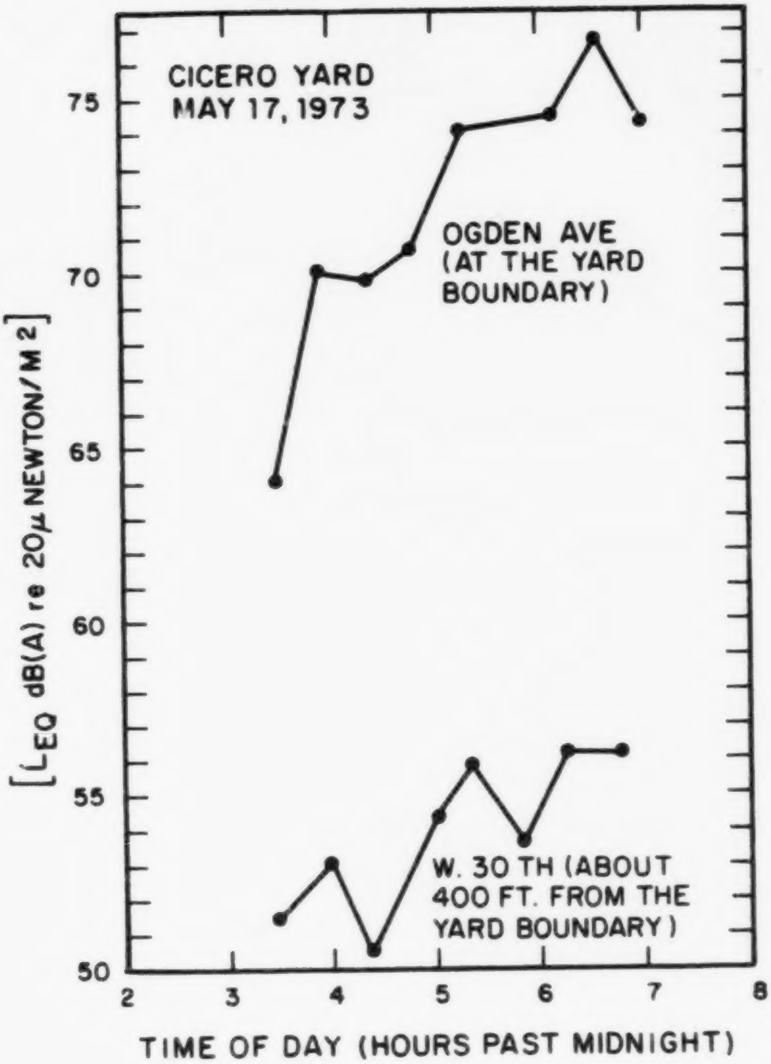


FIG. D.13. MEASURED L_{EQ} VS TIME OF DAY FOR POINTS IN AND NEAR A RAILROAD YARD (20-MIN RECORDINGS, SAMPLED 10 TIMES/SEC).

would be associated with an amount of energy equal to the sum of the energies of a collection of discontinuous sounds. The discontinuous sounds are analyzed for a specified period of time, and L_{EQ} is calculated for that same period. Figure D-13 shows plots of the computer-calculated L_{EQ}'s for the observations described above.

MODELING YARD NOISE IMPACT ON PEOPLE

The two types of railroad switching yards are flat yards and hump yards. In a flat railroad yard there are two major sources of noise – locomotives and car impact. In hump yards the squeal caused by cars passing through retarders is significant.

The development of a yard noise model for this Background Document involves the computation of L_{DN}* for yards which (1) describes the activities of locomotives, (2) determines the probabilities of occurrence of various levels of retarder squeal and car impact noise, and (3) integrates the cumulative acoustic energy that is developed at a given point in the space surrounding the yard.

Figure D.14a shows calculated L_{DN} profiles for group retarders in a typical yard – the Cicero Yard in Chicago. Figure D.14b shows L_{DN} profiles for car-car impacts. Figure D.14c shows L_{DN} profiles for locomotive operations in the yard.

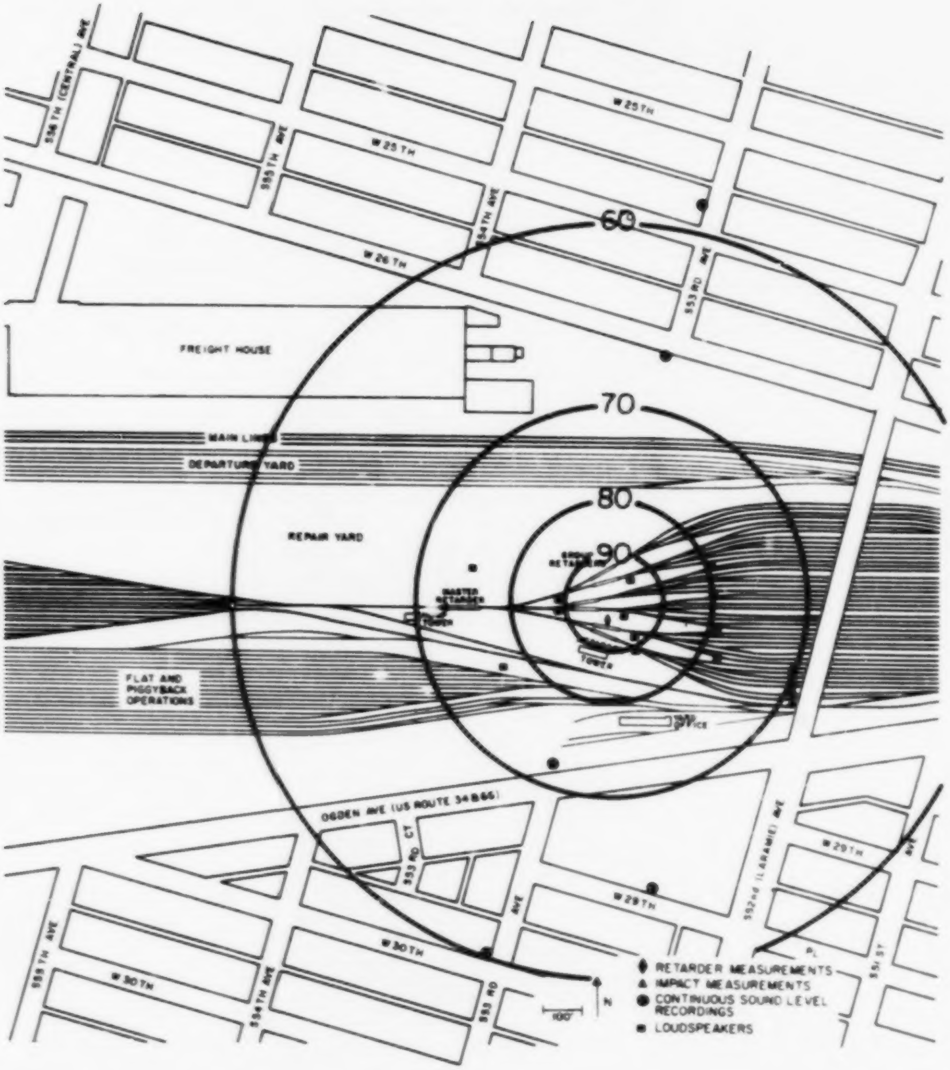
The calculated L_{DN} profiles in Figure D.14 are based on observed levels and frequencies of occurrence of various noises. In addition to the usual geometric attenuation, atmospheric absorption and ground attenuation effects (Beranek, 1971) were included in the construction of the figure. The levels for the individual noise events at the measurement points shown in Figure D.14 were consistent with the points of origin of the events also shown in Figure D.14.

The noise levels for retarders and rail car impacts are considerably lower than those for locomotives, so that the total noise levels from all sources is approximately that of locomotives alone, as shown in Figure D.14. The noise levels determined from magnetic tape recordings of noise emissions at the West 30th measurement point are also in good agreement with the total noise emission levels (approximated by locomotive noise), as noted in Figure D.14c.

Retarder noise levels and impact noise levels in Figure D.14 generally would be dominant at community observation points if the locomotive noise levels were lowered by 10 dB(A). Thus, retarder and car impact noise will replace locomotive noise as the most obtrusive noise in the community near the Cicero Yard, if locomotive exhausts can be muffled sufficiently to lower their noise by 10 dB(A) (assuming that no other sources of locomotive noise produce levels comparable to exhaust noise levels).

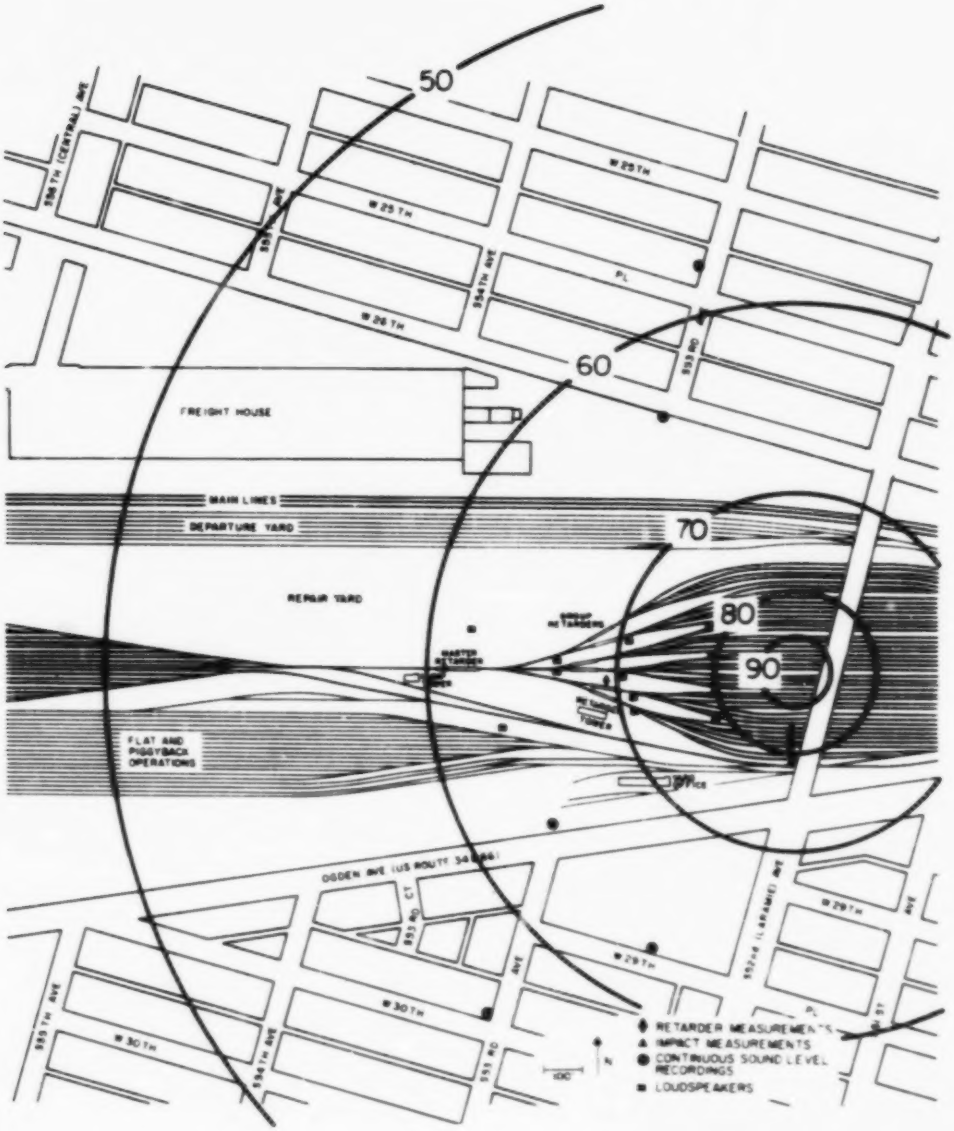
---

*Enclosure A of section 8.


W 25TH
W 25TH
56TH (CENTRAL) AVE
55TH AVE
54TH AVE
W 26TH
53 RD AVE
60
70
80
90
FREIGHT HOUSE
MAIN LINES
DEPARTURE YARD
REPAIR YARD
GROUP RETARDER
MASTER RETARDER
TOWER
TOWER
FLAT AND PIGGYBACK OPERATIONS
YARD OFFICE
OGDEN AVE (US ROUTE 34 & 66)
53 RD CT
52nd (LARAMIE) AVE
W 29TH
W 29TH
PL
51 ST
55TH AVE
W 30TH
W 30TH
54TH AVE
53 RD
AVE
N
100'
RETARDER MEASUREMENTS
IMPACT MEASUREMENTS
CONTINUOUS SOUND LEVEL RECORDINGS
LOUDSPEAKERS

(a) Retarder Squeals

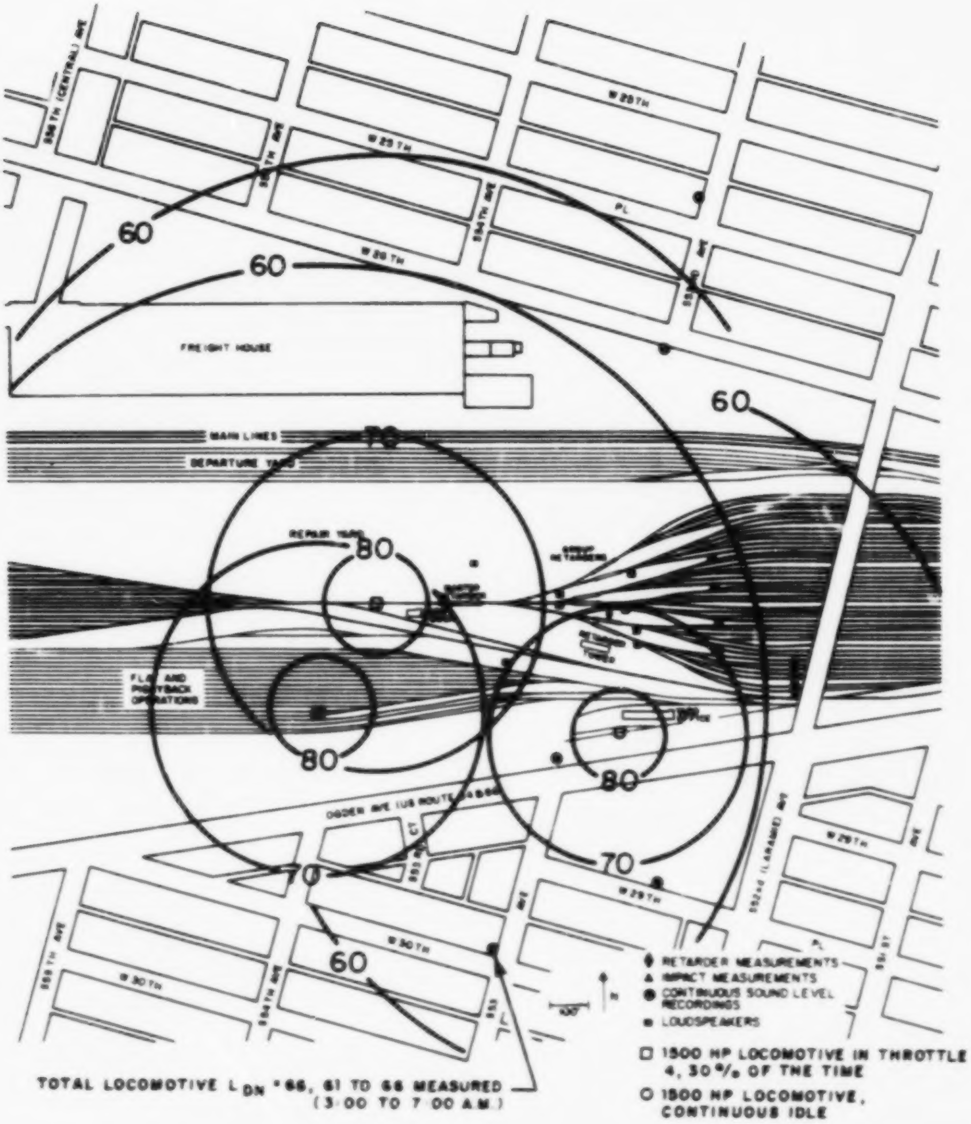
FIG. D.14a. L_{DN} PROFILES FOR BURLINGTON NORTHERN'S CICERO YARD



50
60
70
80
90
5600TH (CENTRAL) AVE
W 25TH
W 26TH
5954TH AVE
PL
FREIGHT HOUSE
MAIN LINES
DEPARTURE YARD
REPAIR YARD
GROUP RETARDERS
MASTER RETARDER
RETARDER TOWER
FLAT AND PIGGYBACK OPERATIONS
OGDEN AVE (US ROUTE 34 & 66)
W 29TH
W 30TH
5952nd (LARAMIE) AVE
RETARDER MEASUREMENTS
IMPACT MEASUREMENTS
CONTINUOUS SOUND LEVEL RECORDINGS
LOUDSPEAKERS
N
100

(b) Impacts

FIG. D.14b. (CONT.)


56TH (CENTRAL) AVE
55TH AVE
54TH AVE
53RD AVE
W 25TH
W 26TH
W 26TH PL
FREIGHT HOUSE
MAIN LINES
DEPARTURE YARD
REPAIR YARD
GROUP RETARDERS
FLAT AND PIGGYBACK OPERATIONS
OGDEN AVE (US ROUTE 34&66)
W 29TH
W 30TH
52ND (LARAMIE) AVE
PL
60
60
60
60
70
70
70
80
80
80
80
RETARDER MEASUREMENTS
IMPACT MEASUREMENTS
CONTINUOUS SOUND LEVEL RECORDINGS
LOUDSPEAKERS
100'
N
TOTAL LOCOMOTIVE L_{DN} =66, 61 TO 66 MEASURED (3:00 TO 7:00 A.M.)
□ 1500 HP LOCOMOTIVE IN THROTTLE 4, 30 % OF THE TIME
○ 1500 HP LOCOMOTIVE, CONTINUOUS IDLE

(c) Locomotives

FIG. D.14c. (CONT.)

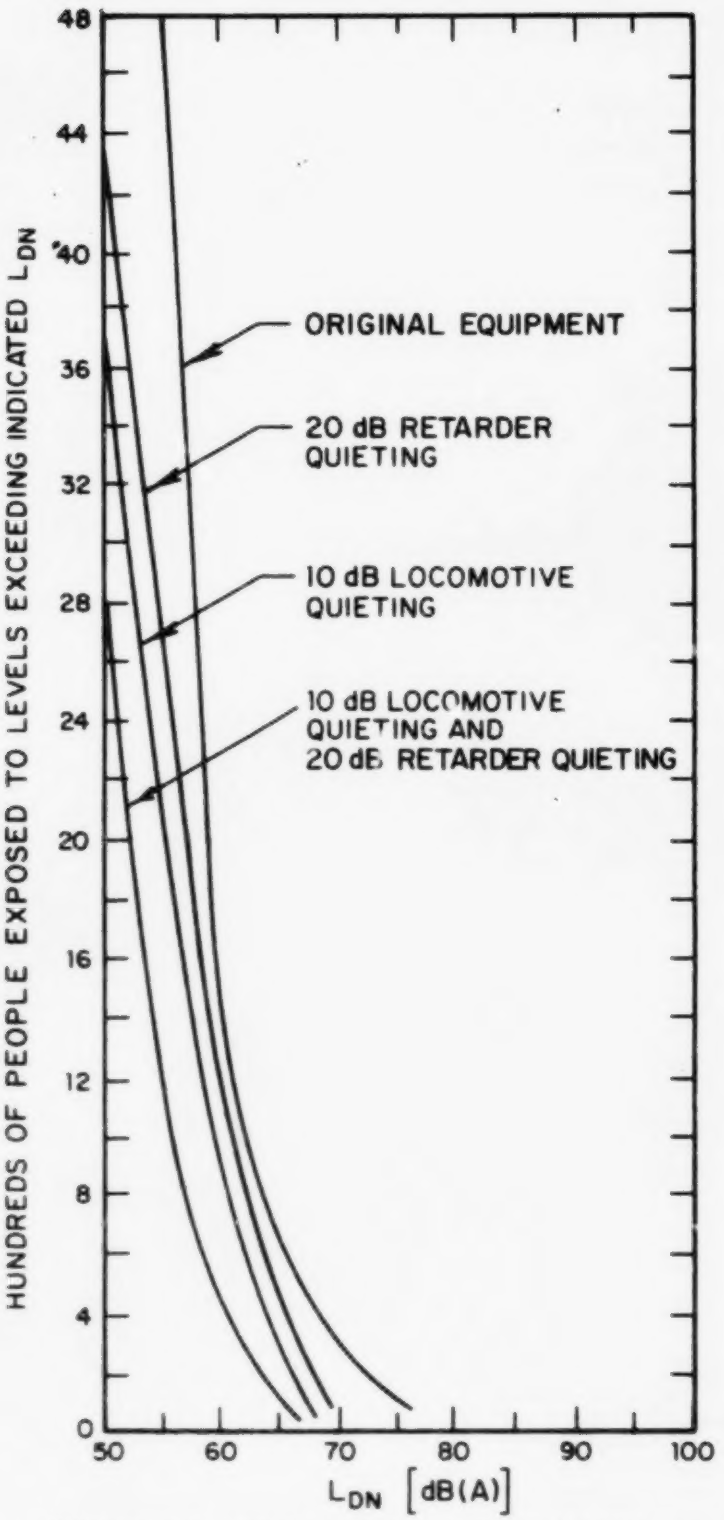


FIG. D.15 NUMBER OF PEOPLE EXPOSED TO VARIOUS L_{DN} BY CICERO YARD OPERATIONS.

Figure D.15 shows the number of people exposed to various L_{dn} around the Cicero Yard.*

Figure D.15 indicates that a muffler which quiets locomotive exhaust noise by 10 dB(A) will decrease by 400 the number of people exposed to L_{dn} of 65 or more from the Cicero Yard operations (assuming that no other sources of locomotive noise produce levels comparable to exhaust noise levels). The figure also shows that barriers providing a 20 dB(A) reduction of retarder noise would decrease by 200 the number of people exposed to L_{dn} of 65 or more.

Analysis in more detail of Figure D.15 shows that at the time of the study, at the Cicero Yard approximately 4,800 people or more were exposed to noise levels higher than the L_{dn} 55 noise level identified in the Levels Document (EPA/ONAC report number 550/9-74-004) as being protective of public health and welfare. Approximately 60 of these individuals were exposed to noise levels at $L_{dn} = 75$, which clearly is in the region where hearing loss may be a potential threat, according to the Levels Document, which identifies the potential hearing loss level at $L_{eq(24)} = 70$ (approximately $L_{dn} = 73$).

The application of mufflers which quiet locomotive exhaust noise by 10 dB(A) is predicted to reduce the number of exposed people (to an L_{dn} of 55 or greater) from 4,800 to 2,000, which is a 58% improvement. From a hearing conservation point of view, the number of exposed people to an L_{dn} of 75 would shrink to zero, or a 100% improvement.

Similarly, the predicted effect of the application of barriers to retarders (see Figure D.15) would be a reduction in the number of people exposed to levels greater than L_{dn} 55 to 2,800, which is a 42% improvement. From a hearing conservation point of view, the number of exposed people would shrink to 0, which is a 100% improvement.

---

*Population densities for use in construction of Figure D.15 were obtained from the U.S. Department of Commerce, Bureau of the Census.

USG 350-74-13

GENERAL MOTORS CORPORATION

LOCOMOTIVE EXHAUST MUFFLER RETROFIT

Cost Study Report No. 1

LOCOMOTIVE MODELS GP49-2, GP40, GP38-2 and GP38

GENERAL MOTORS CORPORATION

NOVEMBER 1, 1974

USG 350-74-13

GM

Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
Warren, Michigan 48090

November 1, 1974

Dr. Alvin F. Meyer, Jr.
Deputy Assistant Administrator
for Noise Control Programs
Environmental Protection Agency
Crystal Mall Building - Room 1115
1921 Jefferson Davis Highway
Arlington, Va. 20460

Dear Dr. Meyer:

Attached are five (5) copies of General Motors Locomotive Exhaust Muffler Retrofit - Cost Study Report No. 1.

This represents the first installment of a study undertaken by Electro-Motive Division to estimate the cost of engine exhaust system hardware and associated locomotive modification deemed necessary to meet the EPA proposed stationary locomotive sound level limit of 87 dBA at 30 meters at any throttle setting.

The first report covers GM (EMD) locomotive models GP40-2, GP40, GP38-2 and GP38. Cost Study Report No. 1 and a series of similar reports to be submitted to EPA will ultimately cover 14 General Motors model locomotives representing a total of 14,789 units delivered by EMD or 63.4% of the 23,307 total GM locomotives in service on Class 1 and 2 Railroads as of January 1, 1974. The figures stated in this initial report are not necessarily representative of the amounts that will be submitted for other locomotive models in subsequent reports.

If you have any questions regarding this report, please do not hesitate to contact me.

Sincerely yours,

E G Ratering

E. G. Ratering, Director
Vehicular Noise Control

Atts. (5)

GENERAL MOTORS CORPORATION
LOCOMOTIVE EXHAUST MUFFLER RETROFIT
COST STUDY REPORT NO. 1

LOCOMOTIVE MODELS GP40-2, GP40, GP38-2, AND GP38

This study is undertaken by General Motors in response to a request by the Environmental Protection Agency to provide cost information that would aid the EPA in evaluating the expense to the railroads of retrofitting in-service locomotives with exhaust muffler hardware to meet the EPA proposed stationary locomotive sound level limit of 87 dB(A) at any throttle setting measured at 30 meters.

During a meeting at the Electro-Motive Division (EMD) of GM on September 26, 1974, EMD advised EPA representatives that it would undertake a "paper study" of the engine exhaust system hardware and associated application modifications of certain EMD locomotive models which would be necessary in order to comply with an 87 dBA sound level. EMD also stated that this retrofit work was not being solicited by General Motors and that EMD locomotive manufacturing facilities were not sufficient to undertake this retrofit work, primarily due to the volume of new locomotive production. This work would presumably be done by the railroads themselves or by others pursuant to contracts with railroads. No attempt has been made to determine the cost for retrofit noise control treatment necessary to achieve compliance with the EPA proposed locomotive noise standard of 67 dBA at 30 meters under stationary idle conditions.

This study was confined to the locomotive configurations as delivered to the railroads by EMD. If there has been subsequent modification, alteration, addition, accident, damage, etc., to a specific locomotive which might affect the time and/or materials necessary to retrofit that locomotive, the estimate for that locomotive would have to be adjusted accordingly. The figures established cover only the effort required to apply the engine exhaust system hardware modifications. They do not include any allowances for the repair of, or added costs resulting from defects, accident damage, etc. which may have to be repaired before retrofit can be accomplished, e.g., there is no provision for radiator repair. Cleaning and painting are confined to only those areas involved in the retrofit modifications.

The estimated retrofit major new hardware would be developed and sold by EMD at EMD Parts Department prices. The miscellaneous hardware are items purchased by EMD from others. The amounts shown for these two classifications of hardware and for EMD labor are based on known, current costs at EMD as of October 1974. None of the amounts contain any provision for future economics, and significant adjustments may be necessary due to inflation and other considerations. The amounts were established on preliminary design information and sketches for engine exhaust system hardware retrofit requirements. Labor costs and miscellaneous new hardware do not include profit on the amount shown, whereas, any contractor that performed retrofit labor services for the railroads would include a mark-up on this labor and on purchased materials. These figures are also predicted on the assumption that sufficient tooling, facilities, and raw materials are available to manufacture the required parts, rebuild the engine turbochargers, alter the locomotive carbodies and perform other operations necessary to retrofit the locomotives and that this could all be done under normal production conditions.

Production line balancing, an important consideration at EMD, is not included in this study. It should be emphasized that the necessary tooling and facilities, and floor space required to retrofit locomotives, manufacture additional quantities of certain piece parts, and rebuild of increased volume of turbochargers do not exist at this time at EMD. Any estimate of the cost of the requisite tooling and facilities could only be determined after retrofit cycle times and a schedule by locomotive model type are established. Once this information is obtained, the amounts stated herein would have to be modified to include such additional tooling and factilities costs since the amounts presented do not contain allowance for this significant area of cost. For example, we estimate that approximately $300,000 in special tools would be required to retrofit these four GP locomotive models at the rate of two units per five-day week assuming two shifts per day.

The stated costs for labor are based upon the labor costs, including burden, presently existing at EMD's LaGrange, Illinois, plant and are not necessarily representative of such costs at railroad maintenance installations or at other sources where retrofit work might be done for the railroads. Furthermore, other sources may have different job codes, shift allowances, etc., applicable to their labor force. Therefore, the labor costs at such other sources would, of necessity, reflect other labor-related differences.

This study report No. 1 is the first in a series of several reports which will be submitted to the EPA to cover ultimately 14 General Motors model locomotives representing a total of 14,789 units delivered by EMD, or 63.4 percent of the 23,307 total GM locomotives in service on Class 1 and 2 Railroads as of January 1, 1974. The figures stated in this initial report are not necessarily representative of the amounts that will be estimated for other locomotive models in subsequent reports.

GENERAL MOTORS LOCOMOTIVE MODEL : GP40-2 (Turbocharged, 3,000 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : January, 1972 to present

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 165

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 0.7%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 0.6%

	MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	20.0%
B.	Standard Dynamic Brakes (Optional)	55.2%
C.	Extended Range Dynamic Brakes (Optional)	24.8%

GP40-2 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive-type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester; therefore the turbocharged engine requires no additional provision for spark arrestance hardware.

A. GP40-2 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. ENGINE MAINTENANCE HATCH

The engine maintenance hatch must be removed from locomotive. The turbocharger removal opening in the hatch must be enlarged to accommodate the exhaust muffler. The hatch is then reapplied to the locomotive.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the engine maintenance hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

A. GP40-2 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 7,100.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 14,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	5 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY*	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 4,500
TOTAL COST	:	$ 18,700

* **Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.**

B. GP40-2 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. DYNAMIC BRAKE HATCH

The dynamic brake hatch must be removed from locomotive. The turbocharger removal opening in the hatch must be enlarged to accommodate the exhaust muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the muffler. The dynamic brake hatch is then reapplied to the locomotive and dynamic brake cabling is reconnected.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

B. GP40-2 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 400.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 7,700.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 14,900
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	6 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 5,000.
TOTAL COST	:	$ 19,900.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.

C. GP40-2 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. EXTENDED RANGE DYNAMIC BRAKE HATCH STRUCTURE

The extended range dynamic brake hatch must be removed from the locomotive. The hatch structure must be modified to shift the hatch assembly seven inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling, conduit, and control wires, lengthened seven inches over the original, must be applied. The extended range dynamic brake hatch is then reapplied to the locomotive and cabling and control wires are reconnected.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcame the additional backpressure created by the exhaust muffler.

C. GP40-2 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure seven inches rearward on locomotive.
4. Dynamic brake cables, conduit, and control wires.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED : $ 6,800.

TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED : $ 500.

TOTAL COST OF LABOR TO MAKE MODIFICATION : $ 10,200

TOTAL EXHAUST MUFFLER RETROFIT COST : $ 17,500

LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME : 7 days

LOCOMOTIVE OUT OF SERVICE TRANSIT TIME : 4 days

LOCOMOTIVE OUT OF SERVICE COST/DAY * : $ 500.

TOTAL LOCOMOTIVE OUT OF SERVICE COST : $ 5,500.

TOTAL COST : $ 23,000.

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* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.

GENERAL MOTORS LOCOMOTIVE MODEL : GP 40 (Turbocharged, 3,000 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : January, 1965 - December, 1971

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 1,202

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 5.2%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 4.0%

	MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE:	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	19.8%
B.	Standard Dynamic Brakes (Optional)	74.0%
C.	Extended Range Dynamic Brakes (Optional)	6.2% *

* Not considered in this study due to low population in field.

GP 40 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive-type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester; therefore the turbocharged engine requires no additional provision for spark arrestance hardware.

A. GP40 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. ENGINE MAINTENANCE HATCH

The engine maintenance hatch must be removed from locomotive. The turbocharger removal opening in the hatch must be enlarged to accommodate the exhaust muffler. The hatch is then reapplied to the locomotive.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the engine maintenance hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

A. GP40 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 7,100.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 14,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	5 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 4,500.
TOTAL COST	:	$ 18,700.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.

B. GP40 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

   The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. DYNAMIC BRAKE HATCH

   The dynamic brake hatch must be removed from locomotive. The turbocharger removal opening in the hatch must be enlarged to accommodate the exhaust muffler. Dynamic brake cabling within the hatch must be removed and rerouted to provide clearance around the muffler. Conduits, heat shields, and insulated panels must be installed to protect dynamic brake cabling in the vicinity of the muffler. The dynamic brake hatch is then reapplied to the locomotive.

3. DYNAMIC BRAKE CABLING

   Dynamic brake cables connecting the electrical control cabinet and the dynamic brake hatch must be removed and rerouted to provide clearance for the muffler. A closure box to protect the cabling near the muffler must be applied.

4. MUFFLER

   An exhaust muffler is installed on the new turbocharger exhaust duct.

5. TURBOCHARGER REMOVAL HATCH COVER

   A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

6. OIL SEPARATOR EJECTOR

   An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

B. GP40 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.
2. Insulated panels, conduit, and sheet metal heat shields.
3. Dynamic brake cabling and associated connectors and cleats.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	: $ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	: $ 800.
TOTAL COST OF LABOR TO MAKE MODIFICATION	: $ 10,500.
TOTAL EXHAUST MUFFLER RETROFIT COST	: $ 18,100.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	: 7 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	: 4 days
LOCOMOTIVE OUT OF SERVICE/DAY*	: $ 500
TOTAL LOCOMOTIVE OUT OF SERVICE COST	: $ 5,500.
TOTAL COST	: $ 23,600

*Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.

GENERAL MOTORS LOCOMOTIVE MODEL : GP38-2 (Roots Blown, 2,000 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : January, 1972 to present

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 538*

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 2.3%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 1.8%

	MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	19.1%
B.	Standard Dynamic Brakes (Optional)	57.3%
C.	Extended Range Dynamic Brakes (Optional)	23.6%**

* This total includes only those locomotives built since May 31, 1972. The remaining 185 GP38-2 locomotives had a different cooling system design (longer) and for retrofit of mufflers are considered with GP38 locomotives.

** Not considered in this study due to time constraints. However, modifications would be similar to those for Standard Dynamic Brakes. Costs would be slightly higher than for Standard Dynamic Brakes due to more extensive hatch work required.

GP38-2 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

The exhaust system consists of a set of engine-mounted spark arresting exhaust manifolds connected in series and terminating in a common outlet. An exhaust muffler is mounted in an opening made in the locomotive carbody roof structure adjacent to the engine cooling system. A flexible connection is applied to couple the engine-mounted exhaust manifolds to the hood-mounted muffler. The muffler is a reactive-type and of straight-through design to minimize backpressure imposed on the engine.

A. GP38-2 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. ENGINE MAINTENANCE HATCH

The engine maintenance hatch must be removed from locomotive. The rear section of the hatch is lengthened approximately 24 inches and the structure is modified by providing an opening and supports to accept an exhaust muffler.

2. LOCOMOTIVE CARBODY

The locomotive carbody to the rear of the air filter compartment must be removed from the locomotive. The carbody structure is modified adjacent to the radiators to accept the lengthened engine maintenance hatch. The carbody is then reapplied and all piping and wiring disconnected to remove the carbody is reconnected.

3. ENGINE EXHAUST MANIFOLDS

The existing exhaust manifolds are removed from the engine and scrapped. A new set of spark arresting exhaust manifolds is applied to the engine including interconnecting hardware between the manifolds. The engine maintenance hatch is then reapplied.

4. MUFFLER

An exhaust muffler is installed in the opening made in the engine maintenance hatch. A flexible connection between the muffler and the exhaust manifolds is applied.

5. COOLING SYSTEM PIPING

A modified engine water outlet casting is required to provide clearance around the exhaust system. Piping between the engine water outlet and the radiators must be altered.

6. MUFFLER HATCH COVER

A muffler hatch cover must be added to cover the exhaust muffler and complete the locomotive carbody roof.

A. GP38-2 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Spark arresting exhaust manifolds and interconnecting hardware.
2. Exhaust muffler.
3. Flexible connection.
4. Muffler hatch cover.
5. Engine water outlet casting.

LISTING OF MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes and sheet used to modify engine maintenance hatch and locomotive carbody.
2. Engine water piping.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	: $ 11,300.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	: $ 500.
TOTAL COST OF LABOR TO MAKE MODIFICATION	: $ 10,800.
TOTAL EXHAUST MUFFLER RETROFIT COST	: $ 22,600
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	: 9 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	: 4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	: $ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	: $ 6,500.
TOTAL COST	: $ 29,100

***Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.**

B. GP38-2 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. DYNAMIC BRAKE HATCH

The dynamic brake hatch must be removed from the locomotive. The rear section of the hatch is lengthened approximately 24 inches and the structure is modified by providing an opening and supports for an exhaust muffler.

2. LOCOMOTIVE CARBODY

The locomotive carbody to the rear of the air filter compartment must be removed from the locomotive. The carbody structure is modified adjacent to the radiators to accept the lengthened engine maintenance hatch. The carbody is then reapplied and all piping and wiring disconnected to remove the carbody is reconnected.

3. ENGINE EXHAUST MANIFOLDS

The existing exhaust manifolds are removed from the engine and scrapped. A new set of spark arresting exhaust manifolds is applied to the engine including interconnecting hardware between the manifolds. The dynamic brake hatch is then reapplied.

4. MUFFLER

An exhaust muffler is installed in the opening made in the dynamic brake hatch. A flexible connection between the muffler and the exhaust manifolds is applied.

5. COOLING SYSTEM PIPING

A modified engine water outlet casting is required to provide clearance around the exhaust system. Piping between the engine water outlet and the radiators must be altered.

6. MUFFLER HATCH COVER

A muffler hatch cover must be added to cover the exhaust muffler and complete the locomotive carbody roof.

B. GP38-2 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Spark arresting exhaust manifolds and interconnecting hardware.
2. Exhaust muffler
3. Flexible connection.
4. Muffler hatch cover.
5. Engine water outlet casting.

LISTING OF MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes and sheet used to modify dynamic brake hatch and locomotive carbody.
2. Engine water piping.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	: $ 11,300.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	: $ 500.
TOTAL COST OF LABOR TO MAKE MODIFICATION	: $ 11,200.
TOTAL EXHAUST MUFFLER RETROFIT COST	: $ 23,000.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	: 9 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	: 4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	: $ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	: $ 6,500.
TOTAL COST	: $ 29,500.

*Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.

GENERAL MOTORS LOCOMOTIVE MODEL : GP38 (Roots Blown, 2, 000 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : January, 1966 to December, 1971

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 977*

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 4.2%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 3.3%

	MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE:	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No dynamic brakes)	15.6%
B.	Standard Dynamic Brakes (Optional)	54.3%
C.	Extended Range Dynamic Brakes (Optional) and Oil Bath Engine Air Filters	12.9%
D.	Extended Range Dynamic Brakes (Optional) and Paper Engine Air Filters	17.2%

*This total includes 185 GP38-2 locomotives which were built with cooling systems similar to GP38 locomotives.

GP38 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

The exhaust system consists of a set of engine-mounted spark arresting exhaust manifolds connected in series and terminating in a common outlet. An exhaust muffler is mounted in an opening made in the locomotive carbody roof structure adjacent to the engine cooling system. A flexible connection is applied to couple the engine-mounted exhaust manifolds to the hood-mounted muffler. The muffler is a reactive-type and of straight-through design to minimize backpressure imposed on the engine.

A. GP38 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKE)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. ENGINE MAINTENANCE HATCH

The engine maintenance hatch must be removed from locomotive. The rear section of the hatch is lengthened approximately 24 inches and the structure is modified by providing an opening and supports to accept an exhaust muffler.

2. LOCOMOTIVE CARBODY AND COOLING SYSTEM

The locomotive carbody to the rear of the air filter compartment must be removed from the locomotive. The existing cooling system and supporting structure must be removed from the carbody. This involves radiators, cooling fans, shutters, piping, electrical wiring, and steel structure. The structure must be rebuilt to accept a shortened radiator set. The two cooling fans must be rebuilt with extra blades. New, shorter shutter assemblies must be installed. The electrical wiring must be relocated. A new fan hatch, and repositioning the fans is required. In addition, the carbody structure must be modified to accept the increased length engine maintenance hatch. The carbody is then reapplied and all piping and wiring disconnected to remove the carbody is reconnected.

3. ENGINE EXHAUST MANIFOLDS

The existing exhaust manifolds are removed from the engine and scrapped. A new set of spark arresting exhaust manifolds is applied to the engine including interconnecting hardware between the manifolds. The engine maintenance hatch is then reapplied.

4. MUFFLER

An exhaust muffler is installed in the opening made in the engine maintenance hatch. A flexible connection between the muffler and the exhaust manifolds is applied.

5. COOLING SYSTEM PIPING

A modified engine water outlet casting is required to provide clearance around the exhaust system. Piping between the engine water outlet and the radiators must be altered.

6. MUFFLER HATCH COVER

A muffler hatch cover must be added to cover the exhaust muffler and complete the locomotive carbody roof.

A. GP38 LOCOMOTIVE – STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Spark arresting exhaust manifolds and interconnecting hardware.
2. Exhaust muffler.
3. Flexible connection.
4. Muffler hatch cover.
5. Engine water outlet casting.
6. Rebuilt cooling fans with extra blades (two).
7. Cooling fan hatch.
8. Radiator support assembly.
9. Radiator shutters.

LISTING OF MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes and sheet used to modify engine maintenance hatch.
2. Steel structural shapes and sheet used to modify cooling system and locomotive carbody.
3. Engine water piping.
4. Conduit and wiring.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 15,000.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 800.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 18,100.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 33,900.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	12 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY*	:	500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	8,000.
TOTAL COST	:	$ 41,900.

*Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.

GP38 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

ESCRIPTION OF MODIFICATIONS NECESSARY TO ACCOMMODATE ETROFIT EXHAUST SYSTEM:

1. DYNAMIC BRAKE HATCH

The dynamic brake hatch must be removed from locomotive. The rear section of the hatch is lengthened approximately 24 inches and the structure is modified by providing an opening and supports for an exhaust muffler.

2. LOCOMOTIVE CARBODY AND COOLING SYSTEM

The locomotive carbody to the rear of the air filter compartment must be removed from the locomotive. The existing cooling system and supporting structure must be removed from the carbody. This involves radiators, cooling fans, shutters, piping, electrical wiring, and steel structure. The structure must be rebuilt to accept a shortened radiator set. The two cooling fans must be rebuilt with extra blades. New, shorter shutter assemblies must be installed. The electrical wiring must be relocated. A new fan hatch and repositioning the fans is required. In addition, the carbody structure must be modified to accept the increased length dynamic brake hatch. The carbody is then reapplied and all piping and wiring disconnected to remove the carbody is reconnected.

3. ENGINE EXHAUST MANIFOLDS

The existing exhaust manifolds are removed from the engine and scrapped. A new set of spark arresting exhaust manifolds is applied to the engine including interconnecting hardware between the manifolds. The dynamic brake hatch is then reapplied.

4. MUFFLER

An exhaust muffler is installed in the opening made in the dynamic brake hatch. A flexible connection between the muffler and the exhaust manifolds is applied.

5. COOLING SYSTEM PIPING

A modified engine water outlet casting is required to provide clearance around the exhaust system. Piping between the engine water outlet and the radiators must be altered.

6. MUFFLER HATCH COVER

A muffler hatch cover must be added to cover the exhaust muffler and complete the locomotive carbody roof.

B. GP38 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Spark arresting exhaust manifolds and interconnecting hardware.
2. Exhaust muffler.
3. Flexible connection.
4. Muffler hatch cover.
5. Engine water outlet casting.
6. Rebuilt cooling fans with extra blades (two).
7. Cooling fan hatch.
8. Radiator support assembly.
9. Radiator shutters.

LISTING OF MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes and sheet used to modify dynamic brake hatch.
2. Steel structural shapes and sheet used to modify cooling system and locomotive carbody.
3. Engine water piping.
4. Conduit and wiring.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED : $ 15,000.

TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED : $ 800.

TOTAL COST OF LABOR TO MAKE MODIFICATION : $ 18,700.

TOTAL EXHAUST MUFFLER RETROFIT COST : $ 34,500.

LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME : 12 days

LOCOMOTIVE OUT OF SERVICE TRANSIT TIME : 4 days

LOCOMOTIVE OUT OF SERVICE COST/DAY * : $ 500.

TOTAL LOCOMOTIVE OUT OF SERVICE COST : $ 8,000.

TOTAL COST : $ 42,500.

*Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, and Penn Central Railroads.

C. GP38 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES AND OIL BATH ENGINE AIR FILTERS

DESCRIPTION OF MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. EXTENDED RANGE DYNAMIC BRAKE HATCH

The extended range dynamic brake hatch must be removed from locomotive. The rear section of the hatch is lengthened approximately 24 inches and the structure is modified by providing an opening and supports for an exhaust muffler.

2. LOCOMOTIVE CARBODY AND COOLING SYSTEM

The locomotive carbody to the rear of the air filter compartment must be removed from the locomotive. The existing cooling system and supporting structure must be removed from the carbody. This involves radiators, cooling fans, shutters, piping, electrical wiring, and steel structure. The structure must be rebuilt to accept a shortened radiator set. The two cooling fans must be rebuilt with extra blades. New, shorter shutter assemblies must be installed. The electrical wiring must be relocated. A new fan hatch and repositioning the fans is required. In addition, the carbody structure must be modified to accept the increased length dynamic brake hatch. The carbody is then reapplied and all piping and wiring disconnected to remove the carbody is reconnected.

3. ENGINE EXHAUST MANIFOLDS

The existing exhaust manifolds are removed from the engine and scrapped. A new set of spark arresting exhaust manifolds is applied to the engine including interconnecting hardware between the manifolds. The dynamic brake hatch is then reapplied.

4. MUFFLER

An exhaust muffler is installed in the opening made in the dynamic brake hatch. A flexible connection between the muffler and the exhaust manifolds is applied.

5. COOLING SYSTEM PIPING

A modified engine water outlet casting is required to provide clearance around the exhaust system. Piping between the engine water outlet and the radiators must be altered.

6. MUFFLER HATCH COVER

A muffler hatch cover must be added to cover the exhaust muffler and complete the locomotive carbody roof.

C. GP38 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES AND OIL BATH ENGINE AIR FILTERS

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Spark arresting exhaust manifolds and interconnecting hardware.
2. Exhaust muffler.
3. Flexible connection.
4. Muffler hatch cover.
5. Engine water outlet casting.
6. Rebuilt cooling fans with extra blades (two).
7. Cooling fan hatch.
8. Radiator support assembly.
9. Radiator shutters.

LISTING OF MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes and sheet used to modify extended range dynamic brake hatch.
2. Steel structural shapes and sheet used to modify cooling system and locomotive carbody.
3. Engine water piping.
4. Conduit and wiring.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	: $ 15,000.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	: $ 800.
TOTAL COST OF LABOR TO MAKE MODIFICATION	: $ 18,900.
TOTAL EXHAUST MUFFLER RETROFIT COST	: $ 34,700.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	: 12 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	: 4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	: $ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	: $ 8,000.
TOTAL COST	: $ 42,700.

*Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads.

D. GP38 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES AND PAPER ENGINE AIR FILTERS

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. EXTENDED RANGE DYNAMIC BRAKE HATCH

The extended range dynamic brake hatch must be removed from locomotive. Approximately 23 inches is removed from the front of the hatch to effectively move the hatch forward on the locomotive. The rear section of the hatch is then lengthened about 47 inches and the structure is modified by providing an opening and supports for an exhaust muffler. Dynamic brake cables, conduit, and control wires must be removed and rerouted.

2. LOCOMOTIVE CARBODY AND COOLING SYSTEM

The locomotive carbody to the rear of the air filter compartment must be removed from the locomotive. The existing cooling system and supporting structure must be removed from the carbody. This involves radiators, cooling fans, shutters, piping, electrical wiring, and steel structure. The structure must be rebuilt to accept a shortened radiator set. The two cooling fans must be rebuilt with extra blades. New, shorter shutter assemblies must be installed. The electrical wiring must be relocated. A new fan hatch and repositioning the fans is required. In addition, the carbody structure must be modified to accept the increased length dynamic brake hatch. The carbody is then reapplied and all piping and wiring disconnected to remove the carbody is reconnected.

3. ENGINE EXHAUST MANIFOLDS

The existing exhaust manifolds are removed from the engine and scrapped. A new set of spark arresting exhaust manifolds is applied to the engine including interconnecting hardware between the manifolds. The dynamic brake hatch is then reapplied.

4. MUFFLER

An exhaust muffler is installed in the opening made in the dynamic brake hatch. A flexible connection between the muffler and the exhaust manifolds is applied.

5. COOLING SYSTEM PIPING

A modified engine water outlet casting is required to provide clearance around the exhaust system. Piping between the engine water outlet and the radiators must be altered.

6. MUFFLER HATCH COVER

A muffler hatch cover must be added to cover the exhaust muffler and complete the locomotive carbody roof.

D. GP38 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES AND PAPER ENGINE AIR FILTERS

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Spark arresting exhaust manifolds and interconnecting hardware.
2. Exhaust muffler.
3. Flexible connection.
4. Muffler hatch cover.
5. Engine water outlet casting.
6. Rebuilt cooling fans with extra blades (two).
7. Cooling fan hatch.
8. Radiator support assembly.
9. Radiator shutters.

LISTING OF MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes and sheet used to modify extended range dynamic brake hatch.
2. Steel structural shapes and sheet used to modify cooling system and locomotive carbody.
3. Engine water piping.
4. Conduit and wiring.
5. Dynamic brake cabling.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED : $ 15,000.

TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED : $ 800.

TOTAL COST OF LABOR TO MAKE MODIFICATION : $ 20,500.

TOTAL EXHAUST MUFFLER RETROFIT COST : $ 36,300.

LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME : 13 days

LOCOMOTIVE OUT OF SERVICE TRANSIT TIME : 4 days

LOCOMOTIVE OUT OF SERVICE COST/DAY * : $ 500.

TOTAL LOCOMOTIVE OUT OF SERVICE COST : $ 8,500.

TOTAL COST : $ 44,800.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Southern, Southern Pacific, and Penn Central Railroads

USG 350-74-16

GENERAL MOTORS CORPORATION

LOCOMOTIVE EXHAUST MUFFLER RETROFIT

COST STUDY REPORT NO. 2

LOCOMOTIVE MODELS GP7, GP9, GP18

GENERAL MOTORS CORPORATION

NOVEMBER 15, 1974

USG 350-74-16

Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
Warren, Michigan 48090

November 15, 1974

Dr. Alvin F. Meyer, Jr.
Deputy Assistant Administrator
for Noise Control Programs
Environmental Protection Agency
Crystal Mall Building - Room 1115
1921 Jefferson Davis Highway
Arlington, Virginia 20460

Dear Dr. Meyer:

In response to your request for Locomotive Exhaust Muffler Retrofit-Cost Study, we are attaching five (5) copies of Report No. 2.

This represents the second installment of a study undertaken by Electro-Motive Division to estimate the cost of engine exhaust system hardware and associated locomotive modification deemed necessary to meet the EPA proposed stationary locomotive sound level limit of 87 dBA at 30 meters at any throttle setting.

The second report covers GM (EMD) locomotive models GP7, GP9, and GP18. It should be pointed out that the proposed exhaust system hardware for these three GP locomotive models is not available and would require further design and performance evaluation with subsequent structural durability testing prior to production usage.

Cost Study Report No. 2 and a series of similar reports to be submitted to EPA will ultimately cover 14 General Motors model locomotives representing a total of 14,789 units delivered by EMD, or 63.4% of the 23,307 total GM locomotives in service on Class 1 and 2 Railroads as of January 1, 1974. The figures stated in this report are not necessarily representative of the amounts that will be submitted for other locomotive models in subsequent reports.

If you have any questions regarding this report, please do not hesitate to contact me.

Sincerely yours,

E. G. Ratering, Director
Vehicular Noise Control

Attachments (5)

GENERAL MOTORS CORPORATION
LOCOMOTIVE EXHAUST MUFFLER REPORT
COST STUDY REPORT NO. 2

LOCOMOTIVE MODELS GP7, GP9, and GP18

This study was undertaken by General Motors in response to a request by the Environmental Protection Agency to provide cost information on the expense to the railroads of retrofitting in-service locomotives with exhaust muffler hardware. Such retrofit would enable a diesel locomotive to meet the EPA proposed stationary locomotive sound level limit of 87 dB (A) at any throttle setting measured at 30 meters.

During a meeting at the Electro-Motive Division (EMD) of GM on September 26, 1974, EMD advised EPA representatives that it would undertake a "paper study" of the engine exhaust system hardware and associated application modifications of certain EMD locomotive models which would be necessary in order to comply with an 87 dB (A) sound level.

EMD also stated that this retrofit work was not being solicited by General Motors and that EMD locomotive manufacturing facilities were not sufficient to undertake this retrofit work, primarily due to the volume of new locomotive production. This work would presumably be done by the railroads themselves or by others pursuant to contracts with railroads.

No attempt has been made to determine the cost for retrofit noise control treatment necessary to achieve compliance with the EPA proposed locomotive noise standard of 67 dB (A) at 30 meters under stationary idle condition.

It should be pointed out that the proposed exhaust system hardware for the three GP locomotive models covered in this second cost study is not available and would require further design and performance evaluation with subsequent structural durability testing prior to production usage.

This study was confined to the locomotive configuration as delivered to the railroads by EMD. If there has been subsequent modification, alteration, addition, accident, damage, etc., to a specific locomotive which might affect the time and/or materials necessary to retrofit that locomotive, the estimate for that locomotive would have to be adjusted accordingly. These data cover only the effort required to apply the engine exhaust system hardware modifications. They do not include any allowances for the repair of, or added costs resulting from defects, accident damage, etc. which may have to be repaired before retrofit can be accomplished, e.g., there is no provision for radiator repair. Cleaning and painting are confined to only those areas involved in the retrofit modifications.

The estimated retrofit major new hardware would have to be developed and sold by EMD at EMD Parts Department prices. The miscellaneous hardware are items which would be purchased by EMD from others. The amounts shown for these two classifications of hardware and for EMD labor are based on known, current costs at EMD as of October 1974. None of the amounts contain any provision for future economics, and significant adjustments may be necessary due to inflation and other considerations. The amounts were established on preliminary design information and sketches for engine exhaust system hardware retrofit requirements.

Labor costs and miscellaneous new hardware do not include profit on the amount shown, whereas, any contractor that performed retrofit labor services for the railroads would include a mark-up on this labor and on purchased materials. These figures are also predicated on the assumption that sufficient tooling, facilities, and raw materials are available to manufacture the required parts, alter the locomotive carbodies, and perform other operations necessary to retrofit the locomotives. Moreover, it is presumed that this could all be done under normal production conditions.

Production line balancing (the utilization of labor in the most equitable and efficient manner) is an important consideration at EMD, but is not included in this study. It should be emphasized that the necessary tooling and facilities, and floor space required to retrofit locomotives and manufacture additional quantities of certain piece parts, do not exist at this time at EMD. Any estimate of the cost of the requisite tooling and facilities could only be determined after retrofit cycle times and a schedule by by locomotive model type are established. Once this information is obtained, the amounts stated herein would have to be modified to include such additional tooling and facilities costs since the amounts presented do not contain allowance for this significant area of cost.

GENERAL MOTORS LOCOMOTIVE MODEL	:	GP7 (Roots Blown, 1,500 HP)
LOCOMOTIVE MODEL PRODUCTION DATES	:	1949 - 1954
NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974	:	2,619
PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974	:	11.2%
PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974	:	8.7%

	MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	85.9%
B.	Standard Dynamic Brakes (Optional)	14.1%
C.	Winterization (Optional) *	24.6%

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* Costs developed with regard to this optional feature are in addition to those established for features A and B listed above. The winterization feature involves the addition of a duct which takes warm air from the radiator and recirculates it to the engine room to melt any snow which has accumulated there. Used on those locomotives which are regularly operated in cold climates.

GENERAL MOTORS LOCOMOTIVE MODEL	:	GP9 (Roots Blown, 1,750 HP)
LOCOMOTIVE MODEL PRODUCTION DATES	:	1954 - 1959
NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974	:	3,480
PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974	:	14.9%
PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974	:	11.6%

MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE		PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	40.2%
B.	Standard Dynamic Brakes (Optional)	59.8%
C.	Winterization (Optional) *	22.8%

* Costs developed with regard to this optional feature are in addition to those established for features A and B listed above. The winterization feature involves the addition of a duct which takes warm air from the radiator and recirculates it to the engine room to melt any snow which has accumulated there. Used on those locomotives which are regularly operated in cold climates.

GENERAL MOTORS LOCOMOTIVE MODEL : GP18 (Roots blown, 1,800 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : 1959 - 1963

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 343

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 1.5%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 1.1%

	MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	74.0%
B.	Standard Dynamic Brakes (Optional)	26.0%
C.	Winterization (Optional) *	7.2%

* Costs developed with regard to this optional feature are in addition to those established for features A and B listed above. The winterization feature involves the addition of a duct which takes warm air from the radiator and recirculates it to the engine room to melt any snow which has accumulated there. Used on those locomotives which are regularly operated in cold climates.

GP7, GP9, and GP18 LOCOMOTIVES

DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

The exhaust system consists of a set of four engine-mounted spark arresting exhaust manifolds connected in pairs and terminating in two flanged outlets. Two exhaust mufflers are mounted directly on the exhaust manifold flanged outlets and protrude through openings made in the roof structure. The weight of the mufflers is supported by the exhaust manifolds which are reinforced to accept the added loads. The muffler is a reactive-type of straight-through design to minimize backpressure imposed on the engine.

A. GP7, GP9, and GP18 LOCOMOTIVES - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. LOCOMOTIVE CARBODY

The locomotive carbody to the rear of the cab must be removed from the locomotive. The existing exhaust stack openings in the carbody roof must be enlarged and the adjacent structure modified to allow the muffler to protrude through the locomotive roof.

2. ENGINE EXHAUST MANIFOLDS

The existing exhaust manifolds are removed from the engine and scrapped. A new set of spark arresting manifolds and interconnecting hardware is applied to the engine. The locomotive carbody is then reapplied and all piping and wiring disconnected to remove the carbody is reconnected.

3. MUFFLER

Two exhaust mufflers are applied to the new engine exhaust manifolds through the openings made in the carbody roof.

4. MUFFLER COVER

A roof-mounted cover is applied over each muffler to protect the muffler and minimize rain intrusion into the locomotive.

A. GP7, GP9, and GP18 LOCOMOTIVES - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Four spark arresting exhaust manifolds and interconnecting hardware.
2. Two exhaust mufflers.
3. Two muffler covers.

LISTING OF MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes used to modify locomotive carbody.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 4,400.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 6,600.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 11,300.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	6 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 5,000.
TOTAL COST	:	$ 16,300.

*Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

B. GP7, GP9, and GP18 LOCOMOTIVES EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. DYNAMIC BRAKE HATCH

The dynamic brake hatch must be removed from the locomotive. The existing exhaust stack openings in the hatch must be enlarged and the structure modified to allow the muffler to protrude through the locomotive roof.

2. ENGINE EXHAUST MANIFOLDS

The existing exhaust manifolds are removed from the engine and scrapped. A new set of spark arresting manifolds and interconnecting hardware is applied to the engine. The dynamic brake hatch is then reapplied and all piping and wiring disconnected to remove the hatch is reconnected.

3. MUFFLER

Two exhaust mufflers are applied to the new engine exhaust manifolds through the openings made in the dynamic brake hatch.

4. MUFFLER COVER

A roof-mounted cover is applied over each muffler to protect the muffler and minimize rain intrusion into the locomotive.

B. GP7, GP9, and GP18 LOCOMOTIVES EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Four spark arresting exhaust manifolds and interconnecting hardware.
2. Two exhaust mufflers.
3. Two muffler covers.

LISTING OF MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes used to modify dynamic brake hatch.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	: $ 4,400.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	: $ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	: $ 5,800.
TOTAL EXHAUST MUFFLER RETROFIT COST	: $ 10,500.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	: 5 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	: 4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	: $ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	: $ 4,500.
TOTAL COST	: $ 15,000.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

c. GP7, GP9, and GP18 LOCOMOTIVES EQUIPPED WITH WINTERIZATION FEATURE

DESCRIPTION OF MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. LOCOMOTIVE CARBODY OR DYNAMIC BRAKE HATCH

A five inch wide section of the winterization opening in the carbody roof or dynamic brake hatch must be altered to allow the rear exhaust muffler to be installed.

2. WINTERIZATION DUCT

The winterization duct must be removed from the locomotive. The duct must be altered by shortening the length of the duct five inches. The duct must then be reapplied to the modified carbody roof or dynamic brake hatch.

C. GP7, GP9, and GP18 LOCOMOTIVES EQUIPPED WITH WINTERIZATION FEATURE

LISTING OF ADDITIONAL MISCELLANEOUS NEW HARDWARE TO BE APPLIED:

1. Steel structural shapes and sheet used to modify carbody roof or dynamic brake hatch.
2. Steel structural shapes and sheet used to modify winterization duct.

TOTAL COST OF ADDITIONAL MISCELLANEOUS NEW HARDWARE REQUIRED : $ - 0 -

TOTAL COST OF ADDITIONAL LABOR TO MAKE MODIFICATION : $ 1,100.

TOTAL ADDITIONAL EXHAUST MUFFLER RETROFIT COST : $ 1,100.

ADDITIONAL LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME : 1 day

LOCOMOTIVE OUT OF SERVICE COST/DAY * : $ 500.

TOTAL ADDITIONAL LOCOMOTIVE OUT OF SERVICE COST : $ 500.

TOTAL ADDITIONAL COST : $ 1,600.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

USG 350-74-17

GENERAL MOTORS CORPORATION

LOCOMOTIVE EXHAUST MUFFLER RETROFIT

COST STUDY REPORT NO. 3

LOCOMOTIVE MODELS SD40, SD40-2, SD45, SD45-2

GENERAL MOTORS CORPORATION

GM

DECEMBER 4, 1974

USG 350-74-17

GM

Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
Warren, Michigan 48090

December 5, 1974

Dr. Alvin F. Meyer, Jr.
Deputy Assistant Administrator
for Noise Control Programs
Environmental Protection Agency
Crystal Mall Building - Room 1115
1921 Jefferson Davis Highway
Arlington, Virginia 20460

Dear Dr. Meyer:

In response to your request for Locomotive Exhaust Muffler Retrofit-Cost Study, we are attaching five (5) copies of Report No. 3.

This represents the third installment of a study undertaken by Electro-Motive Division to estimate the cost of engine exhaust system hardware and associated locomotive modification deemed necessary to meet the EPA proposed stationary locomotive sound level limit of 87 dBA at 30 meters at any throttle setting.

The third report covers GM (EMD) locomotive models SD40-2, SD40, SD45-2, and SD45.

Cost Study Report No. 3 and a series of similar reports to be submitted to EPA will ultimately cover 14 General Motors model locomotives representing a total of 14,789 units delivered by EMD, or 63.4% of the 23,307 total GM locomotives in service on Class 1 and 2 Railroads as of January 1, 1974. The figures stated in this report are not necessarily representative of the amounts that will be submitted for other locomotive models in subsequent reports.

If you have any questions regarding this report, please do not hesitate to contact me.

Sincerely yours,

E. G. Ratering, Director
Vehicular Noise Control

jr

Attachments (5)

GENERAL MOTORS CORPORATION
LOCOMOTIVE EXHAUST MUFFLER RETROFIT
COST STUDY REPORT NO. 3

LOCOMOTIVE MODELS SD40-2, SD40, SD45-2, and SD45

This study is undertaken by General Motors in response to a request by the Environmental Protection Agency (EPA). Its purpose is to provide cost information that would aid the EPA in evaluating the expense to the railroads of retrofitting in-service locomotives with certain exhaust muffler hardware. This hardware would permit the locomotive to meet the EPA proposed stationary locomotive sound level limit of 87 db(A) at any throttle setting measured at 30 meters.

During a meeting at the Electro-Motive Division (EMD) of GM on September 26, 1974, EMD advised EPA representatives that it would undertake a "paper study" of the nature described above.

EMD also stated that this retrofit work was not being solicited by General Motors and that EMD locomotive manufacturing facilities were not sufficient to undertake this retrofit work, primarily due to the volume of new locomotive production. This work would presumably be done by the railroads themselves or by others pursuant to contracts with railroads.

This study does not purport to determine the cost for retrofit noise control treatment necessary to achieve compliance with the EPA proposed locomotive noise standard of 67 db(A) at 30 meters under stationary idle conditions.

The EMD study was confined to the locomotive configurations as delivered by them to the railroads. If there has been subsequent modification, alteration, addition, accident, damage, etc., to a specific locomotive which might affect the time and/or materials necessary to retrofit that locomotive, the estimate for that locomotive would have to be adjusted accordingly. The figures established cover only the effort required to apply the engine exhaust system hardware modifications. They do not include any allowances for the repair of, or added costs resulting from defects, accident damage, etc. which may have to be repaired before retrofit can be accomplished, e.g., there is no provision for radiator repair. Cleaning and painting are confined to only those areas involved in the retrofit modifications.

The estimated retrofit major new hardware would be developed and sold by EMD at EMD Parts Department prices. The miscellaneous hardware are items purchased by EMD from others. The amounts shown for these two classifications of hardware and for EMD labor are based on known, current costs at EMD as of October 1974. None of the amounts contain any provision for future economics, and significant adjustments may be necessary due to inflation and other considerations. The amounts were established on preliminary design information and sketches for engine exhaust system hardware retrofit requirements.

Labor costs and miscellaneous new hardware do not include profit on the amount shown, whereas, any contractor that performed retrofit labor services for the railroads would include a mark-up on this labor and on purchased materials. These figures are also predicated on the assumption that sufficient tooling, facilities, and raw materials are available to manufacture the required parts, rebuild the engine turbochargers, alter the locomotive carbodies and perform other operations necessary to retrofit the locomotives and that this could all be done under normal production conditions.

Production line balancing (the utilization of labor in the most equitable and efficient manner), an important consideration at EMD, is not included in this study. It should be emphasized that the necessary tooling and facilities, and floor space required to retrofit locomotives, manufacture additional quantities of certain piece parts, and rebuild of increased volume of turbochargers do not exist at this time at EMD. Any estimate of the cost of the requisite tooling and facilities could only be determined after retrofit cycle times and a schedule by locomotive model type are established. Once this information is obtained, the amounts stated herein would have to be modified to include such additional tooling and facilities costs since the amounts presented do not contain allowance for this significant area of cost.

The stated costs for labor are based upon the labor costs, including burden, presently existing at EMD's LaGrange, Illinois, plant and are not necessarily representative of such costs at railroad maintenance installations or at other sources where retrofit work might be done for the railroads. Furthermore, other sources may have different job codes, shift allowances, etc., applicable to their labor force. Therefore, the labor costs at such other sources would, of necessity, reflect other labor-related differences.

This study report No. 3 is the third in a series of several reports which will be submitted to the EPA to cover ultimately 14 General Motors model locomotives representing a total of 14,789 units delivered by EMD, or 63.4 percent of the 23,307 total GM locomotives in service on Class 1 and 2 Railroads as of January 1, 1974. The figures stated in this third report are not necessarily representative of the amounts that will be estimated for other locomotive models in subsequent reports.

GENERAL MOTORS LOCOMOTIVE MODEL : SD45-2 (Turbocharged, 3,600 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : January, 1972 to present

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 260

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 1.1%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 0.9%

MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A. Standard Configuration (No Dynamic Brakes)	0%
B. Standard Dynamic Brakes (Optional)	5.0% *
C. Extended Range Dynamic Brakes (Optional)	
1. Welded on hatch	46.5%
2. Bolted on hatch	48.5%

* Not considered in study due to low population in field.

SD45-2 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive-type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester and thereby the turbocharged engine requires no additional provision for spark arrestance hardware.

C.1 SD45-2 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES (WELDED ON HATCH)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. EXTENDED RANGE DYNAMIC BRAKE HATCH STRUCTURE

The extended range dynamic brake hatch must be removed from the locomotive by burning off the welds holding the hatch to the carbody. The hatch structure must be modified to shift the hatch assembly 21 inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling, conduit, and control wires, lengthened 21 inches over the original, must be applied. The extended range dynamic brake hatch is then reapplied to the locomotive and cabling and control wires are reconnected.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

C.1 SD45-2 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES (WELDED ON HATCH)

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure 21 inches rearward on locomotive.
4. Dynamic brake cables, conduit, and control wires.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 600.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 13,500.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 20,900.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	10 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 7,000.
TOTAL COST	:	$ 27,900.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

C.2 SD45-2 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES (BOLTED ON HATCH)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. EXTENDED RANGE DYNAMIC BRAKE HATCH STRUCTURE

The extended range dynamic brake hatch must be removed from the locomotive. The hatch structure must be modified to shift the hatch assembly 21 inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling, conduit, and control wires, lengthened 21 inches over the original, must be applied. The extended range dynamic brake hatch is then reapplied to the locomotive and cabling and control wires are reconnected.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

C.2 SD45-2 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES (BOLTED ON HATCH)

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure 21 inches rearward on locomotive.
4. Dynamic brake cables, conduit, and control wires.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 600.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 10,200.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 17,600.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	8 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 6,000.
TOTAL COST	:	$ 23,600.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroad.

GENERAL MOTORS LOCOMOTIVE MODEL : SD45 (Turbocharged, 3,600 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : 1966 - 1971

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 1,267

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 5.4%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 4.2%

	MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	4.8%
B.	Standard Dynamic Brakes (Optional)	35.3%
C.	Extended Range Dynamic Brakes (Optional)	59.9%

SD45 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive-type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester and thereby the turbocharged engine requires no additional provision for spark arrestance hardware.

A. SD45 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

   The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. ENGINE MAINTENANCE HATCH

   The engine maintenance hatch must be removed from locomotive. The turbocharger removal opening in the hatch must be enlarged to accommodate the exhaust muffler. The hatch is then reapplied to the locomotive.

3. MUFFLER

   An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

   A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the engine maintenance hatch.

5. OIL SEPARATOR EJECTOR

   An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

A. SD45 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES) *

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 7,100.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 14,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	5 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY **	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 4,500.
TOTAL COST	:	$ 18,700.

* Modification considered to be the same for costing as GP40-2 locomotive - Standard Configuration (no dynamic brakes).

** Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

B. SD45 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

   The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. DYNAMIC BRAKE HATCH

   The dynamic brake hatch must be removed from the locomotive. The hatch structure must be modified to shift the hatch assembly 21 inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling and conduit, lengthened 21 inches over the original, must be applied. The dynamic brake hatch is then reapplied to the locomotive and cabling and control wires are reconnected.

3. MUFFLER

   An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

   A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

   An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

B. SD45 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure 21 inches rearward on locomotives.
4. Dynamic brake cables and conduit.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 800.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 11,900.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 19,500
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	8 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 6,000.
TOTAL COST	:	$ 25,500.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

C. SD45 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

   The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. EXTENDED RANGE DYNAMIC BRAKE HATCH STRUCTURE

   The extended range dynamic brake hatch must be removed from the locomotive. The hatch structure must be modified to shift the hatch assembly 21 inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling, conduit, and control wires, lengthened 21 inches over the original, must be applied. The extended range dynamic brake hatch is then reapplied to the locomotive and cabling and control wires are reconnected.

3. MUFFLER

   An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

   A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

   An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

C. SD45 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure 21 inches rearward on locomotive.
4. Dynamic brake cables, conduit, and control wires.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 900.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 11,400.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 19,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	8 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 6,000.
TOTAL COST	:	$ 25,200.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

GENERAL MOTORS LOCOMOTIVE MODEL	:	SD40-2 (Turbocharged, 3,000 HP)
LOCOMOTIVE MODEL PRODUCTION DATES	:	January, 1972 to present
NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974	:	427
PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974	:	1.8%
PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974	:	1.4%

MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A. Standard Configuration (No Dynamic Brakes)	19.1%
B. Standard Dynamic Brakes (Optional)	38.0%
C. Extended Range Dynamic Brakes (Optional)	42.9%

SD40-2 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive-type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester and thereby the turbocharged engine requires no additional provision for spark arrestance hardware.

A. SD40-2 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. ENGINE MAINTENANCE HATCH

The engine maintenance hatch must be removed from locomotive. The turbocharger removal opening in the hatch must be enlarged to accommodate the exhaust muffler. The hatch is then reapplied to the locomotive.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the engine maintenance hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

A. SD40-2 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES) *

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	: $ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	: $ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	: $ 7,100.
TOTAL EXHAUST MUFFLER RETROFIT COST	: $ 14,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	: 5 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	: 4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY **	: $ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	: $ 4,500.
TOTAL COST	: $ 18,700.

* Modification considered to be the same for costing as GP40-2 locomotive - Standard Configuration (no dynamic brakes).

** Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

B. SD40-2 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGERS

   The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. DYNAMIC BRAKE HATCH

   The dynamic brake hatch must be removed from the locomotive. The hatch structure must be modified to shift the hatch assembly nine inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling and conduit, lengthened nine inches over the original, must be applied. The dynamic brake hatch is then reapplied to the locomotive and cabling is reconnected.

3. MUFFLER

   An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

   A new,larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

   An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

B. SD40-2 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure nine inches rearward on locomotive.
4. Dynamic brake cables and conduit.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 600.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 10,900.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 18,300.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	8 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 6,000.
TOTAL COST	:	$ 24,300.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

C. SD40-2 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. EXTENDED RANGE DYNAMIC BRAKE HATCH STRUCTURE

The extended range dynamic brake hatch must be removed from the locomotive. The hatch structure must be modified to shift the hatch assembly 12 inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling, conduit, and control wires, lengthened 12 inches over the original, must be applied. The extended range dynamic brake hatch is then reapplied to the locomotive and cabling and control wires are reconnected.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

C. SD40-2 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure 12 inches rearward on locomotive.
4. Dynamic brake cables, conduit, and control wires.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 500.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 11,400.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 18,700.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	9 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COS	:	$ 6,500.
TOTAL COST	:	$ 25,200.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

GENERAL MOTORS LOCOMOTIVE MODEL : SD40 (Turbocharged, 3,000 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : 1966 - 1971

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 877

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 3.8%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 2.9%

MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE		PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	10.2%
B.	Standard Dynamic Brakes (Optional)	23.5%
C.	Extended Range Dynamic Brakes (Optional)	66.3%
D.	Winterization (Optional)	1.1% *

* Not considered in this study due to low population in field.

SD40 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive-type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester and thereby the turbocharged engine requires no additional provision for spark arrestance hardware.

A. SD40 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. ENGINE MAINTENANCE HATCH

The engine maintenance hatch must be removed from locomotive. The turbocharger removal opening in the hatch must be enlarged to accommodate the exhaust muffler. The hatch is then reapplied to the locomotive.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the engine maintenance hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

A. SD40 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES) *

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 7,100.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 14,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	5 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY **	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 4,500.
TOTAL COST	:	$ 18,700.

* Modification considered to be the same for costing as GP40-2 locomotive - Standard Configuration (No Dynamic Brakes).

** Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

B. SD40 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. DYNAMIC BRAKE HATCH

The dynamic brake hatch must be removed from the locomotive. The hatch structure must be modified to shift the hatch assembly nine inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling and conduit, lengthened nine inches over the original,must be applied. The dynamic brake hatch is then reapplied to the locomotive and cabling is reconnected.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

B. SD40 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure nine inches rearward on locomotive.
4. Dynamic brake cables and conduit.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	: $ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	: $ 900.
TOTAL COST OF LABOR TO MAKE MODIFICATION	: $ 12,500.
TOTAL EXHAUST MUFFLER RETROFIT COST	: $ 20,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	: 8 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	: 4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	: $ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	: $ 6,000.
TOTAL COST	: $ 26,200.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

C. SD40 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

   The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. EXTENDED RANGE DYNAMIC BRAKE HATCH STRUCTURE

   The extended range dynamic brake hatch must be removed from the locomotive. The hatch structure must be modified to shift the hatch assembly nine inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling, conduit, and control wires, lengthened nine inches over the original, must be applied. The extended range dynamic brake hatch is then reapplied to the locomotive and cabling and control wires are reconnected.

3. MUFFLER

   An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

   A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

   An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

C. SD40 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure nine inches rearward on locomotive.
4. Dynamic brake cables, conduit, and control wires.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 900.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 13,300.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 21,000.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	8 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 6,000.
TOTAL COST	:	$ 27,000.

* Based on information furnished by Burlington Northern, Milwaukee Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

USG 350-74-18

GENERAL MOTORS CORPORATION

LOCOMOTIVE EXHAUST MUFFLER RETROFIT

COST STUDY REPORT NO. 4

LOCOMOTIVE MODELS GP30, GP35, SD35

GENERAL MOTORS CORPORATION

DECEMBER 11, 1974

USG 350-74-18

Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
Warren, Michigan 48090

December 11, 1974

Dr. Alvin F. Meyer, Jr.
Deputy Assistant Administrator
for Noise Control Programs
Environmental Protection Agency
Crystal Mall Building - Room 1115
1921 Jefferson Davis Highway
Arlington, Virginia 20460

Dear Dr. Meyer:

In response to your request for Locomotive Exhaust Muffler Retrofit-Cost Study, we are attaching five (5) copies of Report No. 4. Also attached is one (1) copy of General Motors Corporation Locomotive Exhaust Muffler Retrofit Application Illustrations.

This represents the fourth and final installment of a study undertaken by Electro-Motive Division to estimate the cost of engine exhaust system hardware and associated locomotive modification deemed necessary to meet the EPA proposed stationary locomotive sound level limit of 87 dBA at 30 meters at any throttle setting.

The fourth report covers GM (EMD) locomotive models GP30, GP35, and SD35.

Cost Study Report No. 4 and a series of similar reports submitted to EPA cover 14 General Motors model locomotives representing a total of 14,789 units delivered by EMD, or 63.4% of the 23,307 total GM locomotives in service on Class 1 and 2 Railroads as of January 1, 1974. The figures stated in this final report are not necessarily representative of the amounts that have been submitted for other locomotive models in previous reports.

If you have any questions regarding this report, please do not hesitate to contact me.

Sincerely yours,

E. G. Ratering, Director
Vehicular Noise Control

jr
Attachments (6)

GENERAL MOTORS CORPORATION
LOCOMOTIVE EXHAUST MUFFLER RETROFIT
COST STUDY REPORT NO. 4

LOCOMOTIVE MODELS GP30, GP35, and SD35

This study is undertaken by General Motors in response to a request by the Environmental Protection Agency (EPA) to provide cost information that would aid the EPA in evaluating the expense to the railroads of retrofitting in-service locomotives with exhaust muffler hardware. This hardware would permit the locomotive to meet the EPA proposed stationary locomotive sound level limit of 87 dB(A) at any throttle setting measured at 30 meters.

During a meeting at the Electro-Motive Division (EMD) of GM on September 26, 1974, EMD advised EPA representatives that it would undertake a "paper study" of the nature described above.

EMD also stated that this retrofit work was not being solicited by General Motors and that EMD locomotive manufacturing facilities were not sufficient to undertake this retrofit work, primarily due to the volume of new locomotive production. This work would presumably be done by the railroads themselves or by others pursuant to contracts with railroads.

No attempt has been made to determine the cost for retrofit noise control treatment necessary to achieve compliance with the EPA proposed locomotive noise standard of 67 dB(A) at 30 meters under stationary idle conditions.

This study was confined to the locomotive configurations as delivered to the railroads by EMD. If there has been subsequent modification, alteration, addition, accident, damage, etc., to a specific locomotive which might affect the time and/or materials necessary to retrofit that locomotive, the estimate for that locomotive would have to be adjusted accordingly. The figures established cover only the effort required to apply the engine exhaust system hardware modifications. They do not include any allowances for the repair of, or added costs resulting from defects, accident damage, etc. which may have to be repaired before retrofit can be accomplished, e.g., there is no provision for radiator repair. Cleaning and painting are confined to only those areas involved in the retrofit modifications.

The estimated retrofit major new hardware would be developed and sold by EMD at EMD Parts Department prices. The miscellaneous hardware are items purchased by EMD from others. The amounts shown for these two classifications of hardware and for EMD labor are based on known, current costs at EMD as of October 1974. None of the amounts contain any provision for future economics, and significant adjustments may be necessary due to inflation and other considerations. The amounts were established on preliminary design information and sketches for engine exhaust system hardware retrofit requirements.

Labor costs and miscellaneous new hardware do not include profit on the amount shown, whereas, any contractor that performed retrofit labor services for the railroads would include a mark-up on this labor and on purchased materials. These prices are also predicated on the assumption that sufficient tooling, facilities, and raw materials are available to manufacture the required parts, rebuild the engine turbochargers, alter the locomotive carbodies and perform other operations necessary to retrofit the locomotives and that this could all be done under normal production conditions.

Production line balancing (the utilization of labor in the most equitable and efficient manner), an important consideration at EMD, is not included in this study. It should be emphasized that the necessary tooling and facilities, and floor space required to retrofit locomotives, manufacture additional quantities of certain piece parts, and rebuild of increased volume of turbochargers do not exist at this time at EMD. Any estimate of the cost of the requisite tooling and facilities could only be determined after retrofit cycle times and a schedule by locomotive model type are established. Once this information is obtained, the amounts stated herein would have to be modified to include such additional tooling and facilities costs since the amounts presented do not contain allowance for this significant area of cost.

The stated costs for labor are based upon the labor costs, including burden, presently existing at EMD's LaGrange, Illinois, plant and are not necessarily representative of such costs at railroad maintenance installations or at other sources where retrofit work might be done for the railroads. Furthermore, other sources may have different job codes, shift allowances, etc., applicable to their labor force. Therefore, the labor costs at such other sources would, of necessity, reflect other labor-related differences.

This study report No. 4 is the last in a series of four reports which have been submitted to the EPA to cover ultimately 14 General Motors model locomotives representing a total of 14,789 units delivered by EMD, or 63.4 percent of the 23,307 total GM locomotives in service on Class 1 and 2 Railroads as of January 1, 1974. The figures stated in this final report are not necessarily representative of the amounts that have been estimated for other locomotive models in previous reports.

At the end of this report is a locomotive exhaust muffler retrofit cost study summary table which is included along with observations made as a result of this study and related Electro-Motive experience.

GENERAL MOTORS LOCOMOTIVE MODEL : GP30 (Turbocharged, 2,250 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : 1962 - 1963

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 946

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 4.1%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 3.2%

	MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	0.0%
B.	Standard Dynamic Brakes (Optional)	87.8%
C.	Extended Range Dynamic Brakes (Optional)	12.2%

GP30 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester and thereby the turbocharged engine requires no additional provision for spark arrestance hardware.

B. GP30 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. DYNAMIC BRAKE HATCH

The locomotive carbody, containing the dynamic brake hatch (welded on), must be removed from the locomotive. The turbocharger removal opening in the carbody must be enlarged to accommodate the exhaust muffler. Dynamic brake cabling must be removed and rerouted to provide clearance around the muffler. Heat shields and insulated panels must be installed to protect dynamic brake cabling in the vicinity of the muffler. The locomotive carbody is then reapplied to the locomotive.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

B. GP30 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	$ 6,700.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	$ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	$ 9,200.
TOTAL EXHAUST MUFFLER RETROFIT COST	$ 16,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	7 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	$ 5,500.
TOTAL COST	$ 21,700.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

C. GP30 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. EXTENDED RANGE DYNAMIC BRAKE HATCH STRUCTURE

The locomotive carbody, containing the dynamic brake hatch (welded on), must be removed from the locomotive. The extended range dynamic brake contactors must be relocated within the dynamic brake hatch. This involves structural modifications and recabling. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. The locomotive carbody is then reapplied to the locomotive.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

C. GP30 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake contactors.
4. Dynamic brake cables, conduit, and control wires.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED : $ 6,700.

TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED : $ 500.

TOTAL COST OF LABOR TO MAKE MODIFICATION : $ 11,000.

TOTAL EXHAUST MUFFLER RETROFIT COST : $ 18,200.

LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME : 9 days

LOCOMOTIVE OUT OF SERVICE TRANSIT TIME : 4 days

LOCOMOTIVE OUT OF SERVICE COST/DAY * : $ 500.

TOTAL LOCOMOTIVE OUT OF SERVICE COST : $ 6,500.

TOTAL COST : $ 24,700.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific.

GENERAL MOTORS LOCOMOTIVE MODEL : GP35 (Turbocharged, 2,500 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : 1963 - 1965

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 1,308

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 5.6%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 4.4%

MAJOR FEATURES AFFECTING AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A. Standard Configuration (No Dynamic Brakes)	18.1%
B. Standard Dynamic Brakes (Optional)	57.7%
C. Extended Range Dynamic Brakes (Optional)	
1. Welded on hatch	18.6% *
2. Bolted on hatch	5.6% **

* Not considered in study due to time constraints; however, modifications would be similar to those required for GP30 locomotive equipped with Extended Range Dynamic Brakes. Costs would be slightly higher due to more extensive hatch modifications and cable alterations.

** Not considered in study due to low population in field. However, modifications would be similar to those required for GP40-2 locomotive equipped with extended range dynamic brakes.

GP35 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive-type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester and thereby the turbocharged engine requires no additional provision for spark arrestance hardware.

A. GP35 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. LOCOMOTIVE CARBODY

The locomotive carbody to the rear of the cab must be removed from locomotive. The turbocharger removal opening in the carbody must be enlarged to accommodate the exhaust muffler. The carbody is then reapplied to the locomotive.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

ew, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the locomotive carbody.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

A. GP35 LOCOMOTIVE - STANDARD CONFIGURATION (NO DYNAMIC BRAKES)

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 300.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 8,400.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 15,500.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	7 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 5,500.
TOTAL COST	:	$ 21,000.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

B. GP35 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new, reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. LOCOMOTIVE CARBODY

The locomotive carbody containing the dynamic brake hatch (welded on), must be removed from locomotive. The turbocharger removal opening in the hatch must be enlarged to accommodate the exhaust muffler. Dynamic brake cabling within the hatch must be removed and rerouted to provide clearance around the muffler. Conduits, heat shields, and insulated panels must be installed to protect dynamic brake cabling in the vicinity of the muffler. The locomotive carbody is then reapplied to the locomotive.

3. DYNAMIC BRAKE CABLING

Dynamic brake cables connecting the electrical control cabinet and the dynamic brake hatch in the carbody must be removed and rerouted to provide clearance for the muffler. A closure box to protect the cabling near the muffler must be applied.

4. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

5. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

6. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

B. GP35 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structural shapes used to enlarge turbocharger removal opening.
2. Insulated panels, conduit, and sheet metal heat shields.
3. Dynamic brake cabling and associated connectors and cleats.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 700.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 12,700.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 20,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	10 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 7,000.
TOTAL COST	:	$ 27,200.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Rock Island, Penn Central, Southern, and Southern Pacific Railroads.

GENERAL MOTORS LOCOMOTIVE MODEL : SD35 (Turbocharged, 2,500 HP)

LOCOMOTIVE MODEL PRODUCTION DATES : 1964 - 1966

NO. OF LOCOMOTIVES PRODUCED AS OF JANUARY, 1974 : 380

PERCENTAGE OF TOTAL GM LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 1.6%

PERCENTAGE OF TOTAL LOCOMOTIVES IN FIELD SERVICE AS OF JANUARY, 1974 : 1.3%

	MAJOR FEATURES AFFECTIVE AVAILABLE EXHAUST MUFFLER SPACE	PERCENTAGE OF TOTAL MODEL PRODUCTION
A.	Standard Configuration (No Dynamic Brakes)	3.1% *
B.	Standard Dynamic Brakes (Optional)	40.6%
C.	Extended Range Dynamic Brakes (Optional)	56.3%

* Not considered in study due to low population in field. However, modifications would be similar to those required for GP35 locomotive - Standard Configuration (no dynamic brakes).

SD35 LOCOMOTIVE

VERBAL DESCRIPTION OF MUFFLER SYSTEM, INCLUDING SPARK ARRESTING WHERE NECESSARY, TAKING INTO ACCOUNT OPTIONAL FEATURES:

A reactive-type exhaust muffler is installed directly on the turbocharger exhaust outlet duct. The muffler is of straight-through design to minimize backpressure imposed on the engine. The weight of the muffler is supported solely by the turbocharger and, as a result, a special reinforced turbocharger exhaust duct is required. Any electrical cabling must be shielded from the exhaust muffler heat radiation.

The turbocharger is considered an inherently effective spark arrester and thereby the turbocharged engine requires no additional provision for spark arrestance hardware.

B. SD35 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. DYNAMIC BRAKE HATCH

The locomotive carbody, containing the dynamic brake hatch (welded on), must be removed from the locomotive. The dynamic brake hatch must be removed from the locomotive by burning off the welds holding the hatch to the carbody. The hatch structure must be modified to shift the hatch assembly nine inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling and conduits lengthened nine inches over the original, must be applied. The dynamic brake hatch is then reapplied to the locomotive and cabling is reconnected.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

B. SD35 LOCOMOTIVE EQUIPPED WITH STANDARD DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure nine inches rearward on locomotive.
4. Dynamic brake cables and conduits.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 900.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 15,800.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 23,500.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	10 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 7,000.
TOTAL COST	:	$ 30,500.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, Penn Central, Rock Island, Southern, and Southern Pacific Railroads.

C. SD35 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

DESCRIPTION OF LOCOMOTIVE MODIFICATIONS NECESSARY TO ACCOMMODATE RETROFIT EXHAUST SYSTEM:

1. TURBOCHARGER

The turbocharger must be removed from engine, disassembled, inspected, and a new reinforced exhaust duct applied. The turbocharger is then tested and reapplied to the engine.

2. EXTENDED RANGE DYNAMIC BRAKE HATCH STRUCTURE

The locomotive carbody, containing the dynamic brake hatch (welded on), must be removed from the locomotive. The extended range dynamic brake hatch must be removed from the locomotive carbody by burning off the welds holding the hatch to the carbody. The hatch structure must be modified to shift the hatch assembly nine inches toward the rear of the locomotive. The turbocharger removal opening must be enlarged to accommodate the muffler. Insulated panels must be installed to protect dynamic brake cabling in the vicinity of the exhaust muffler. Dynamic brake cabling, conduit, and control wires, lengthened nine inches over the original, must be applied. The extended range dynamic brake hatch is then reapplied to the locomotive and cabling and control wires are reconnected.

3. MUFFLER

An exhaust muffler is installed on the new turbocharger exhaust duct.

4. TURBOCHARGER REMOVAL HATCH COVER

A new, larger hatch cover must be applied above the exhaust muffler to cover the enlarged turbocharger removal opening in the dynamic brake hatch.

5. OIL SEPARATOR EJECTOR

An ejector must be added to the oil separator to overcome the additional backpressure created by the exhaust muffler.

C. SD35 LOCOMOTIVE EQUIPPED WITH EXTENDED RANGE DYNAMIC BRAKES

LISTING OF MAJOR NEW HARDWARE TO BE APPLIED:

1. Turbocharger disassembly, inspection, machining, and application of new, reinforced exhaust duct.
2. Exhaust muffler.
3. Turbocharger removal hatch cover.
4. Oil separator ejector.

LISTING OF MISCELLANEOUS NEW HARDWARE REQUIRED:

1. Steel structure shapes used to enlarge turbocharger removal opening.
2. Insulated panel heat shields.
3. Steel structural shapes and sheet used to relocate dynamic brake hatch structure nine inches rearward on locomotive.
4. Dynamic brake cables, conduit, and control wires.

TOTAL PRICE OF MAJOR NEW HARDWARE REQUIRED	:	$ 6,800.
TOTAL COST OF MISCELLANEOUS NEW HARDWARE REQUIRED	:	$ 900.
TOTAL COST OF LABOR TO MAKE MODIFICATION	:	$ 16,500.
TOTAL EXHAUST MUFFLER RETROFIT COST	:	$ 24,200.
LOCOMOTIVE OUT OF SERVICE PLANT CYCLE TIME	:	10 days
LOCOMOTIVE OUT OF SERVICE TRANSIT TIME	:	4 days
LOCOMOTIVE OUT OF SERVICE COST/DAY *	:	$ 500.
TOTAL LOCOMOTIVE OUT OF SERVICE COST	:	$ 7,000.
TOTAL COST	:	$ 31,200.

* Based on information furnished by Burlington Northern, Milwaukee, Missouri Pacific, PennCentral, Rock Island, Southern, and Southern Pacific Railroads.

GENERAL MOTORS CORPORATION

LOCOMOTIVE EXHAUST MUFFLER RETROFIT
COST STUDY SUMMARY TABLE

AND

OBSERVATIONS MADE AS A RESULT OF THIS
STUDY AND RELATED ELECTRO-MOTIVE EXPERIENCE

GENERAL MOTORS CORPORATION
LOCOMOTIVE EXHAUST MUFFLER RETROFIT COST STUDY SUMMARY

Locomotive Models	GP7	GP9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
No. of Locos. Produced As of January 1974	[illegible]	3480	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1357	290	977	538
Percentage Of Total GM Units In Field Service As of Jan. 1974	11.2%	14.9%	1.5%	4.1%	5.6%	1.8%	[illegible]	0.7%	3.0%	1.0%	5.4%	1.1%	4.2%	2.3%
Percentage of Total Locomotives In Field Service As of January 1974 *	8.7%	11.6%	1.1%	3.2%	4.4%	1.3%	4.0%	0.6%	2.3%	1.4%	4.2%	0.9%	3.3%	1.8%
Total Exhaust Muffler Retrofit Cost (Millions)	30.01	39.53	3.83	15.56	24.63	[illegible]	20.83	2.54	17.45	7.50	28.16	4.75	33.94	12.33
Total Cost Including Muffler Retrofit Plus Out of Service Cost (Millions)	43.21	55.24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31.67	6.35	43.84	15.83

Total overall muffler retrofit and out of service cost [illegible] General Motors Model locomotives representing a total of 16,789 units delivered by EMD, or 67.4 percent of the total [illegible] GM locomotives in service on Class 1 and 2 railroads as of January 1, 1974: $328.86 million

* Based on 30,000 [illegible]

OBSERVATIONS MADE AS A RESULT OF THIS STUDY AND RELATED ELECTRO-MOTIVE EXPERIENCE:

1. The magnitude of costs established in this study to retrofit in-service locomotives with exhaust muffler hardware is indicative of the modification complexity involved to not only meet EPA proposed 87 dB(A) sound level limit but to insure retention of satisfactory overall locomotive performance, reliability, and maintainability as well as exhaust spark arrestance control where necessary.

2. The length of locomotive *"out of service plant cycle"* time established in this study to retrofit in-service locomotives with exhaust muffler hardware raises a serious question as to the practicability of the EPA proposed four year time period for the railroads to obtain proven exhaust muffler hardware and retrofit all of their in-service locomotives to meet 87 dB(A) sound level limit compliance.

3. The length of field service evaluation is normally two years. Electro-Motive's experience in the design and development of locomotive exhaust system hardware has proven that the importance of adequate field test time to insure prototype muffler design structural integrity cannot be over-emphasized. The ultimate realistic determination of muffler structural reliability must take place on the intended locomotive model involved with sufficient field service time experience under actual revenue operating conditions.

4. It should be emphasized that the costs developed in this study do not include additional tooling and facility costs necessary to implement the locomotive exhaust muffler retrofit. This additional significant area of cost can only be determined after retrofit cycle times and a schedule by locomotive model types have been established.

5. In view of this study covering 63.4 percent or 14,789 units out of a total of 23,307 General Motors locomotives in service as of January 1, 1974, the following projection of the costs established in this study is suggested to estimate total retrofit cost for the remaining 36.6 percent or 8518 locomotives:

A. 30 percent or 6992 units -

use GP7 model cost of $15,000/unit. [a]

B. 3.6 percent or 839 units -

use average SD40 model cost of $25,970/unit. [b]

C. 3.0 percent or 687 units -

use average GP7/9/18 model cost of $16,150/unit. [c]

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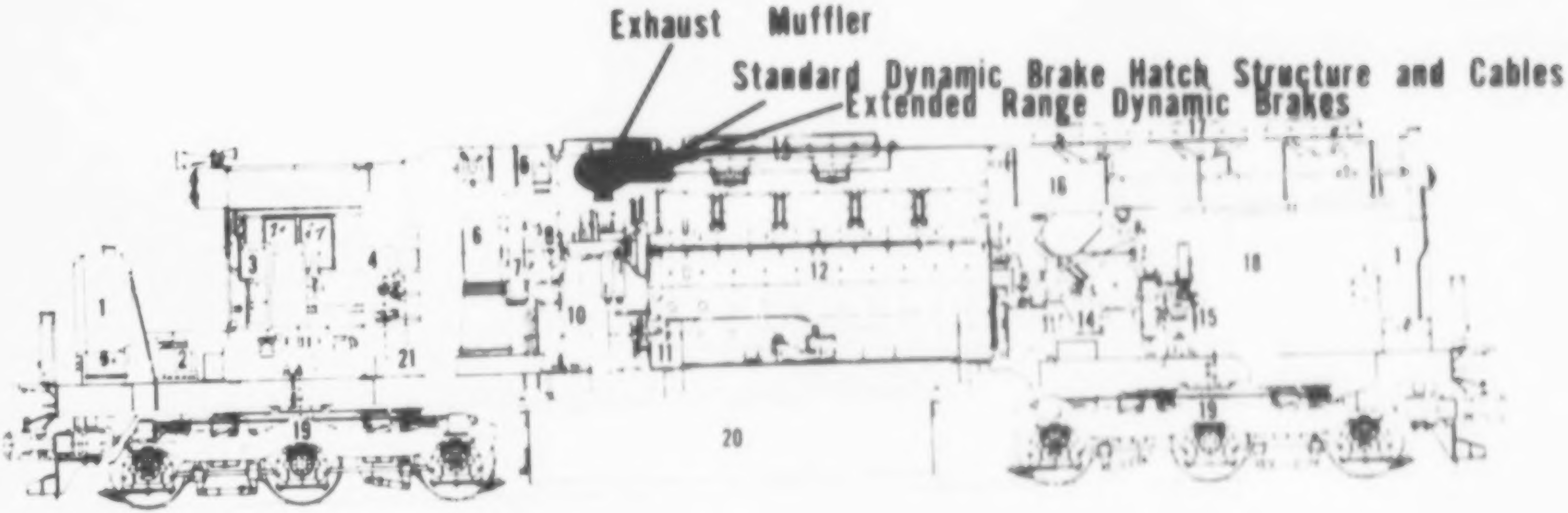
[a] The majority of these units are of the switcher or lower horsepower type such that modifications to the exhaust system of these units would be similar to those needed for the GP7 model.

[b] These units are turbocharged road locomotives and would require modifications similar to those needed on the SD40 units.

[c] These units are the remaining lower horsepower units not individually studied and would require modifications similar to those on the GP7 GP9 and GP18 units.


Exhaust Muffler
Standard Dynamic Brake Hatch Structure and Cables
Extended Range Dynamic Brakes
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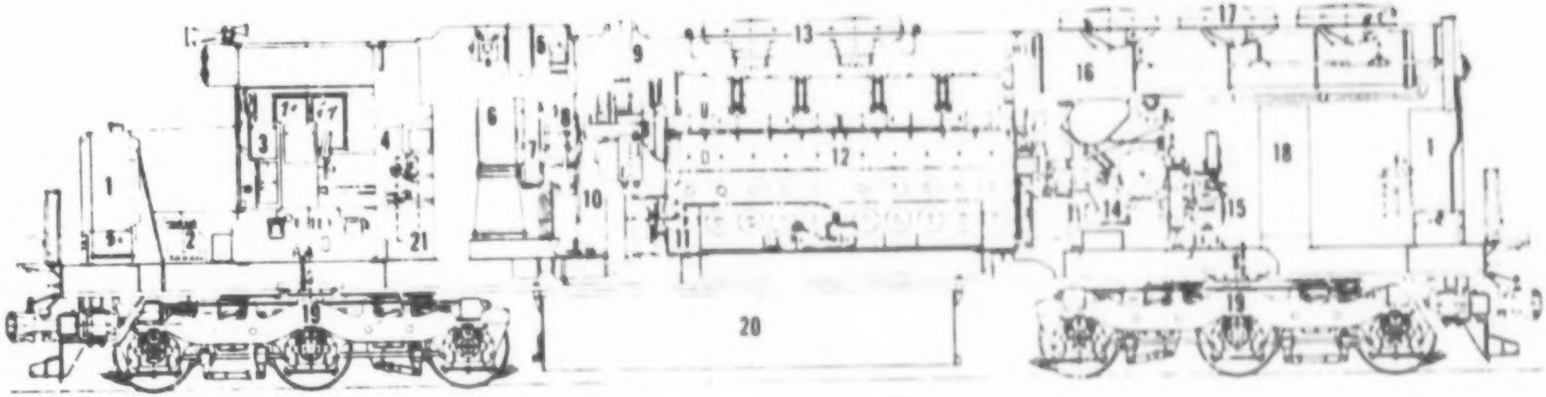
1. Sand Box
2. Battery
3. Control Stand
4. No. 1 Electrical Cabinet
5. Inertial Air Filter
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Turbocharger
10. Main Generator
11. Engine Cranking Motors
12. Engine 20-645E3
13. Dynamic Brake Fans
14. Equipment Rack
15. Air Compressor
16. Radiators
17. Radiator Cooling Fans
18. No. 2 Electrical Cabinet
19. Trucks
20. Fuel Tank
21. Electrical Cabinet Air Filter

General Arrangement — SD45 Locomotive

SD 45/45-2

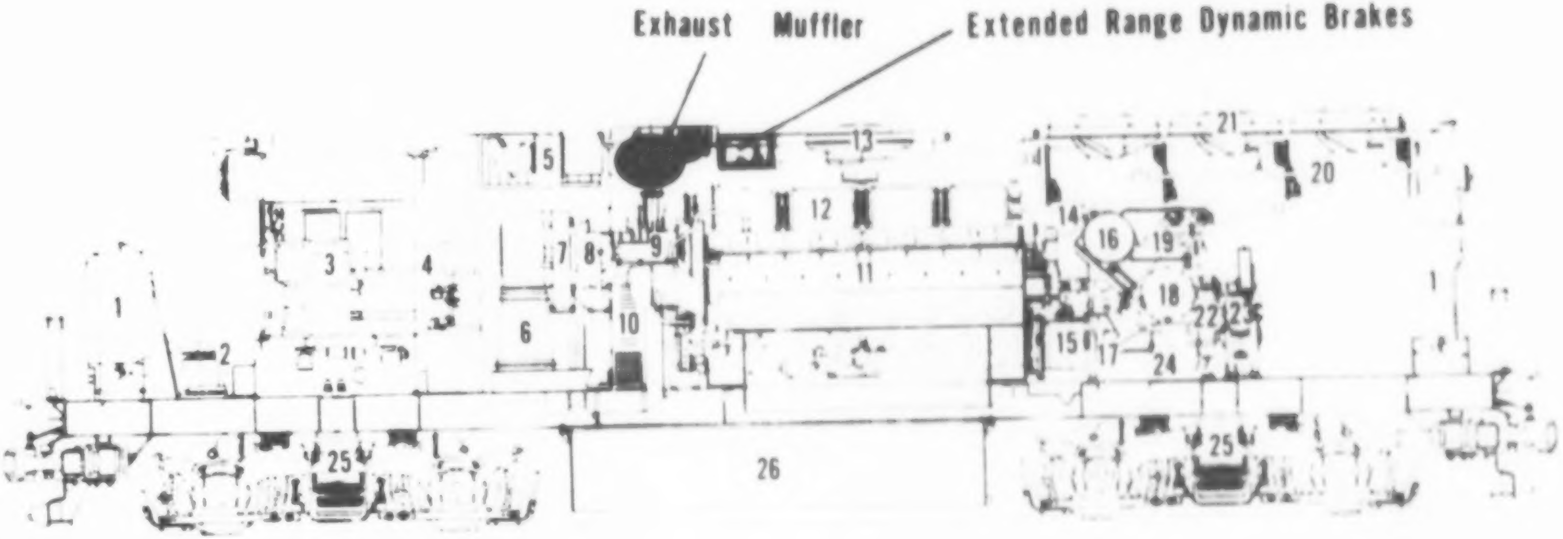
MODIFIED



1. **Sand Box**
2. **Battery**
3. **Control Stand**
4. **No. 1 Electrical Cabinet**
5. **Inertial Air Filter**
6. **Traction Motor Blower**
7. **Generator Blower**
8. Auxiliary Generator
9. Turbocharger
10. Main Generator
11. Engine Cranking Motors
12. Engine 20-645E3
13. Dynamic Brake Fans
14. Equipment Rack
15. Air Compressor
16. Radiators
17. Radiator Cooling Fans
18. No. 2 Electrical Cabinet
19. Trucks
20. Fuel Tank
21. Electrical Cabinet Air Filter

General Arrangement — SD45 Locomotive

SD 45/45-2 STANDARD


Exhaust
Muffler
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1. Sand Box
2. Battery
3. Locomotive Controls
4. Electrical Cabinet
5. Carbody Air Filter
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Turbocharger
10. Main Generator
11. Engine 16-645
12. Exhaust Manifold
13. Dynamic Brake Fan
14. Engine Governor
15. Lube Oil Strainer
16. Engine Water Tank
17. Fuel Pump
18. Lube Oil Filters
19. Lube Oil Cooler
20. Radiators
21. Radiator Fans
22. Fuel Filter
23. Air Compressor
24. AC And Compressor Control Cabinet (Back Of Equipment Rack)
25. Truck
26. Fuel Tank

Locomotive General Arrangement
GP 40/40-2

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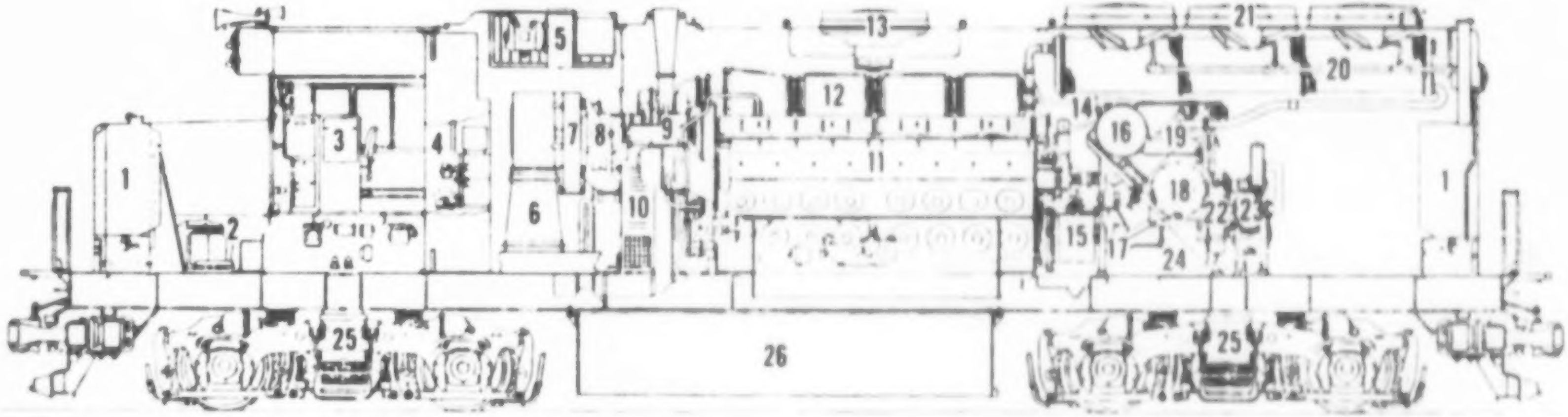
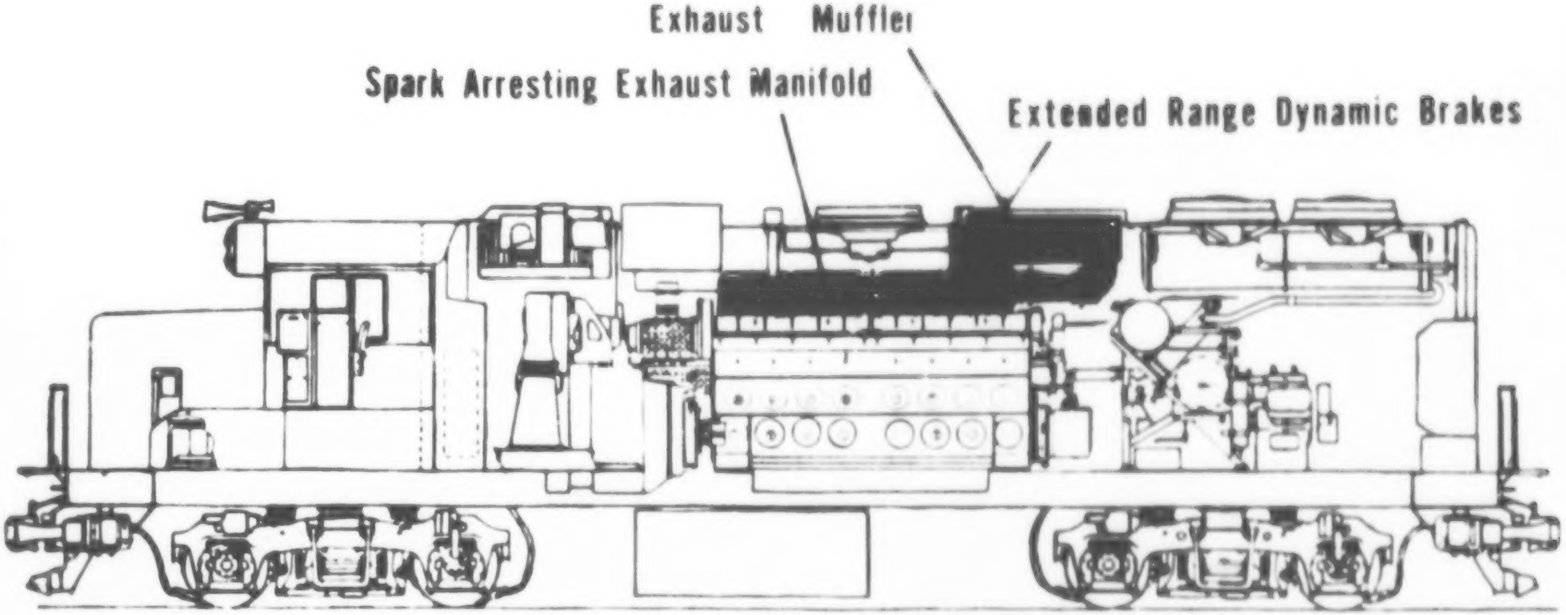


1. Sand Box
2. Battery
3. Locomotive Controls
4. Electrical Cabinet
5. Carbody Air Filter
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Turbocharger
10. Main Generator
11. Engine 16-645
12. Exhaust Manifold
13. Dynamic Brake Fan
14. Engine Governor
15. Lube Oil Strainer
16. Engine Water Tank
17. Fuel Pump
18. Lube Oil Filters
19. Lube Oil Cooler
20. Radiators
21. Radiator Fans
22. Fuel Filter
23. Air Compressor
24. AC And Compressor Control Cabinet (Back Of Equipment Rack)
25. Truck
26. Fuel Tank

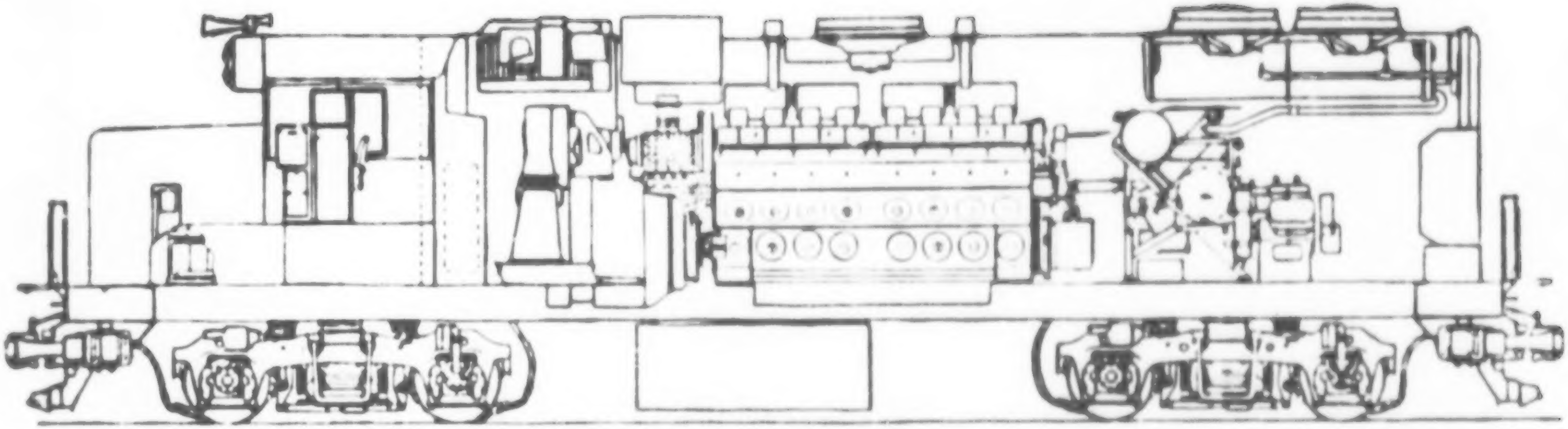
Locomotive General Arrangement

GP 40/40-2 STANDARD

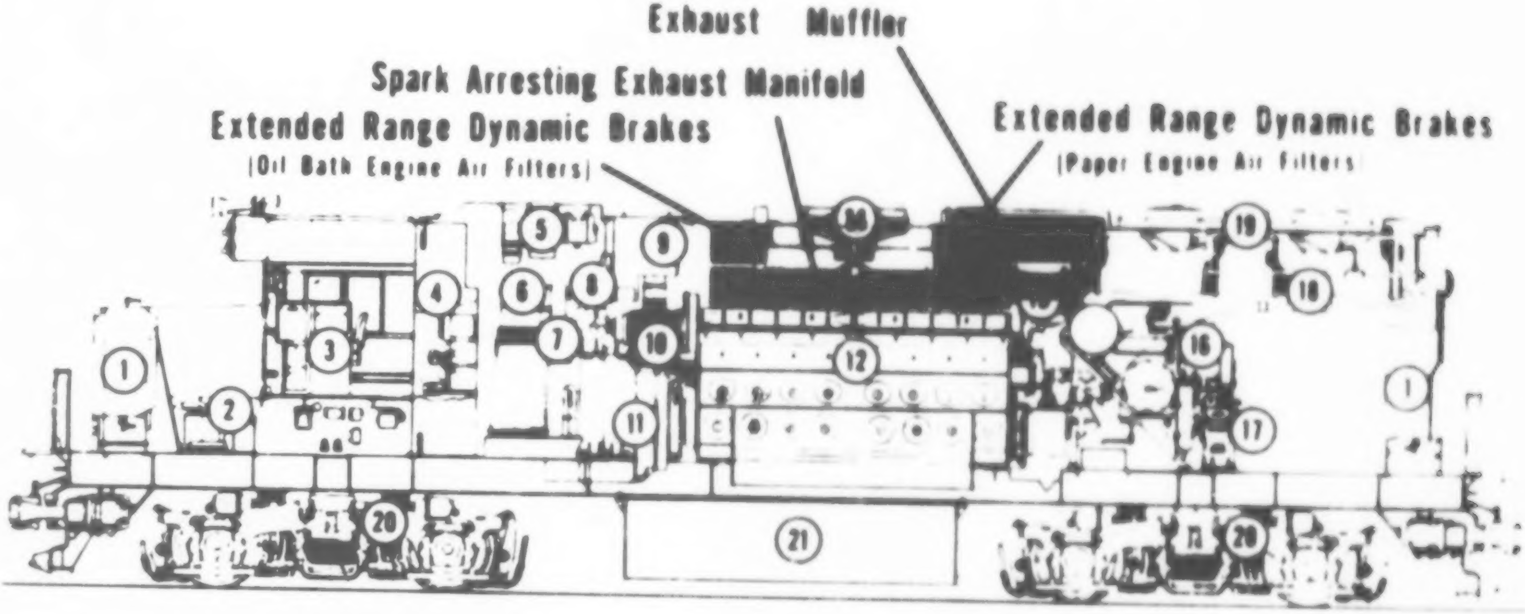

Exhaust Muffler
Spark Arresting Exhaust Manifold
Extended Range Dynamic Brakes

GP 38-2

[illegible]



GP 38-2 STANDARD


Exhaust Muffler
Spark Arresting Exhaust Manifold
Extended Range Dynamic Brakes
(Oil Bath Engine Air Filters)
Extended Range Dynamic Brakes
(Paper Engine Air Filters)
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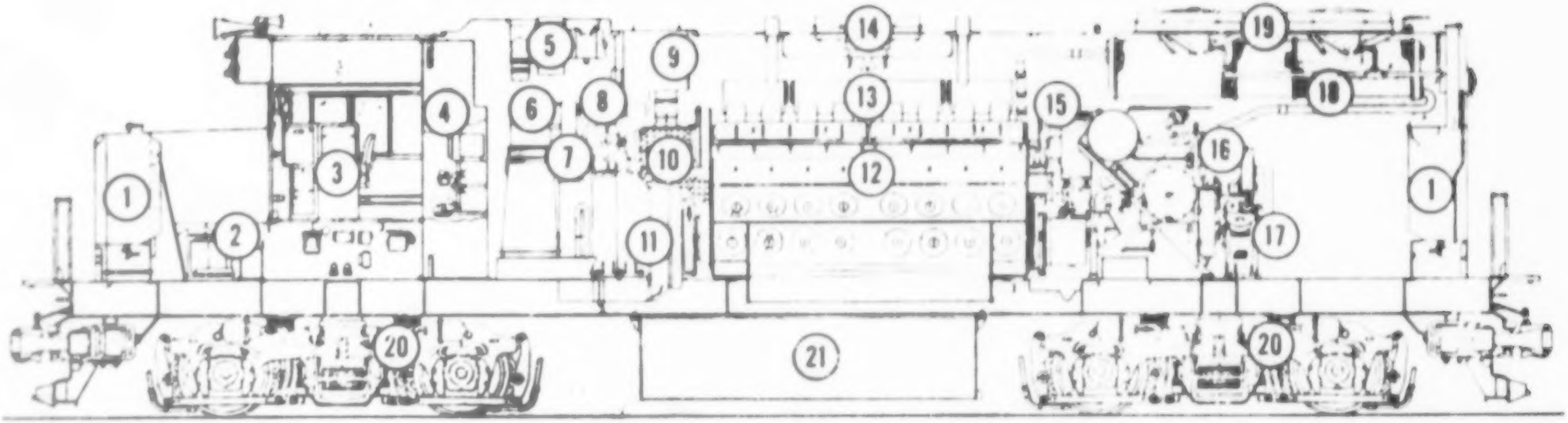
1. Sand Box
2. Battery
3. Locomotive Controls
4. Electrical Cabinet
5. Carbody Air Filter
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Engine Air Filter
10. Engine Blowers
11. DC Main Generator And AC Alternator
12. Engine 16-645E
13. Exhaust Manifolds
14. Dynamic Brake Fan
15. Engine Governor
16. Accessory Rack
17. Air Compressor
18. Radiators
19. Radiator Fans
20. Trucks
21. Fuel Tank

MODIFIED

Locomotive General Arrangement

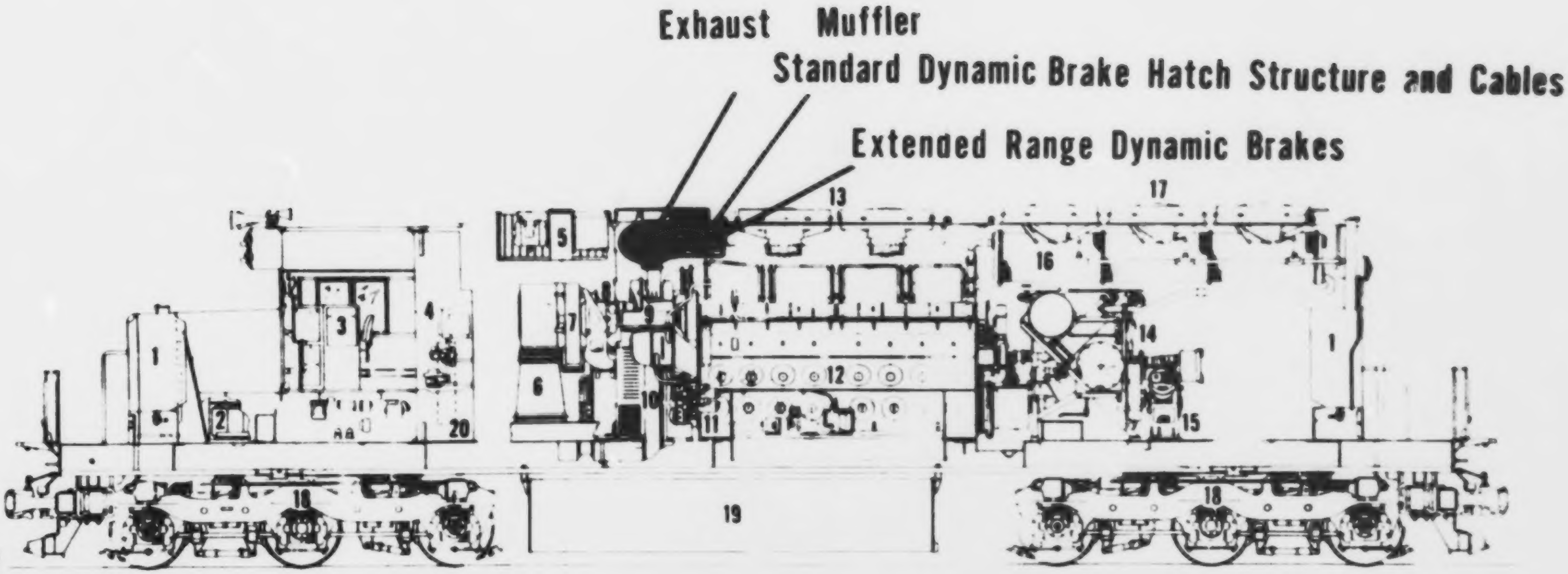
GP 38



1. Sand Box
2. Battery
3. Locomotive Controls
4. Electrical Cabinet
5. Carbody Air Filter
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Engine Air Filter
10. Engine Blowers
11. DC Main Generator And AC Alternator
12. Engine 16-645E
13. Exhaust Manifolds
14. Dynamic Brake Fan
15. Engine Governor
16. Accessory Rack
17. Air Compressor
18. Radiators
19. Radiator Fans
20. Trucks
21. Fuel Tank

GP-38 STANDARD

Locomotive General Arrangement


Exhaust Muffler
Standard Dynamic Brake Hatch Structure and Cables
Extended Range Dynamic Brakes
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1. Sand Box
2. Battery
3. Control Stand
4. No. 1 Electrical Cabinet
5. Inertial Air Filter
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Turbocharger
10. Main Generator
11. Engine Cranking Motors
12. Engine 16-645E3
13. Dynamic Brake Fans
14. Equipment Rack
15. Air Compressor
16. Radiators
17. Radiator Cooling Fans
18. Trucks
19. Fuel Tank
20. Electrical Cabinet Air Filter

General Arrangement -- SD40 Locomotive

SD 35/40/40-2

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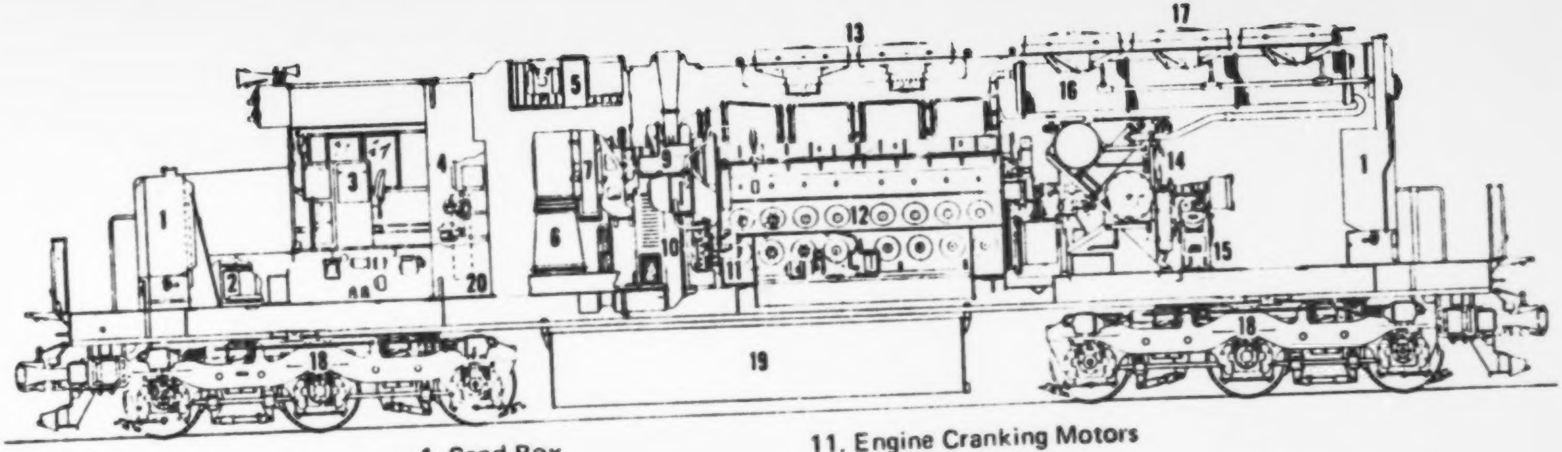
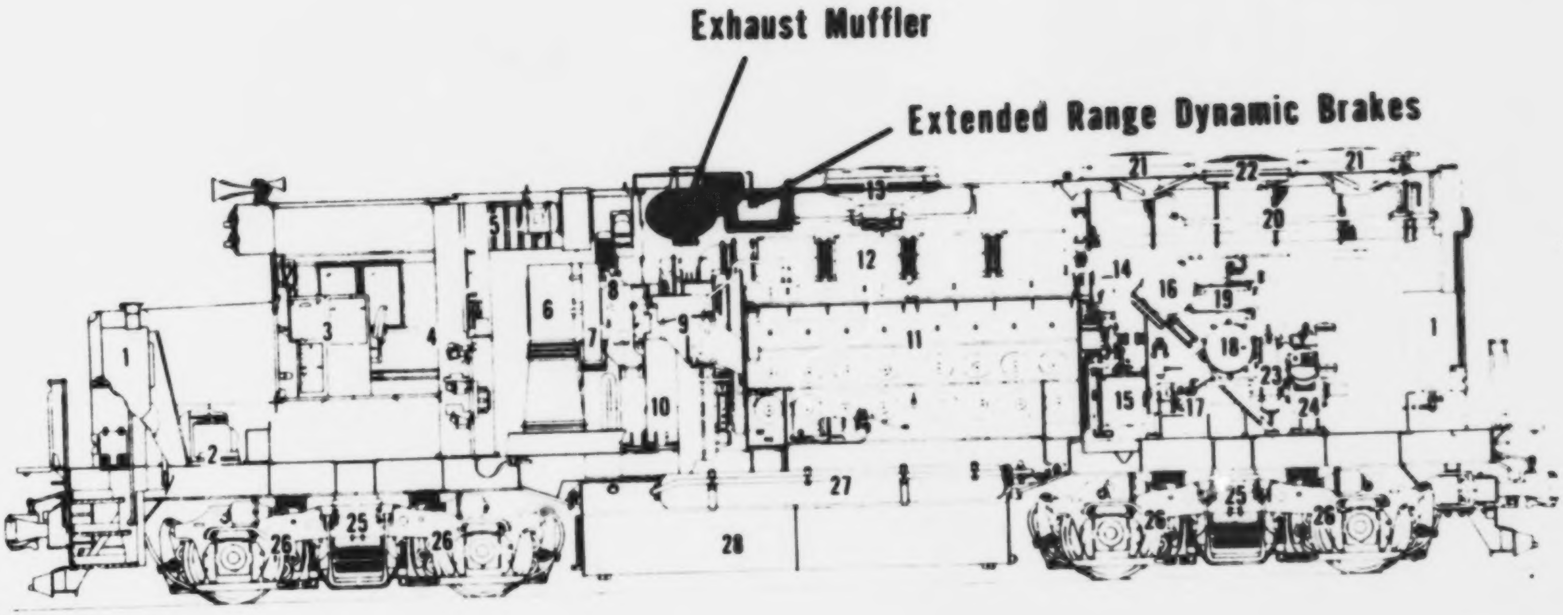


1. Sand Box
2. Battery
3. Control Stand
4. No. 1 Electrical Cabinet
5. Inertial Air Filter
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Turbocharger
10. Main Generator
11. Engine Cranking Motors
12. Engine 16-645E3
13. Dynamic Brake Fans
14. Equipment Rack
15. Air Compressor
16. Radiators
17. Radiator Cooling Fans
18. Trucks
19. Fuel Tank
20. Electrical Cabinet Air Filter

General Arrangement – SD40 Locomotive


Exhaust Muffler
Extended Range Dynamic Brakes
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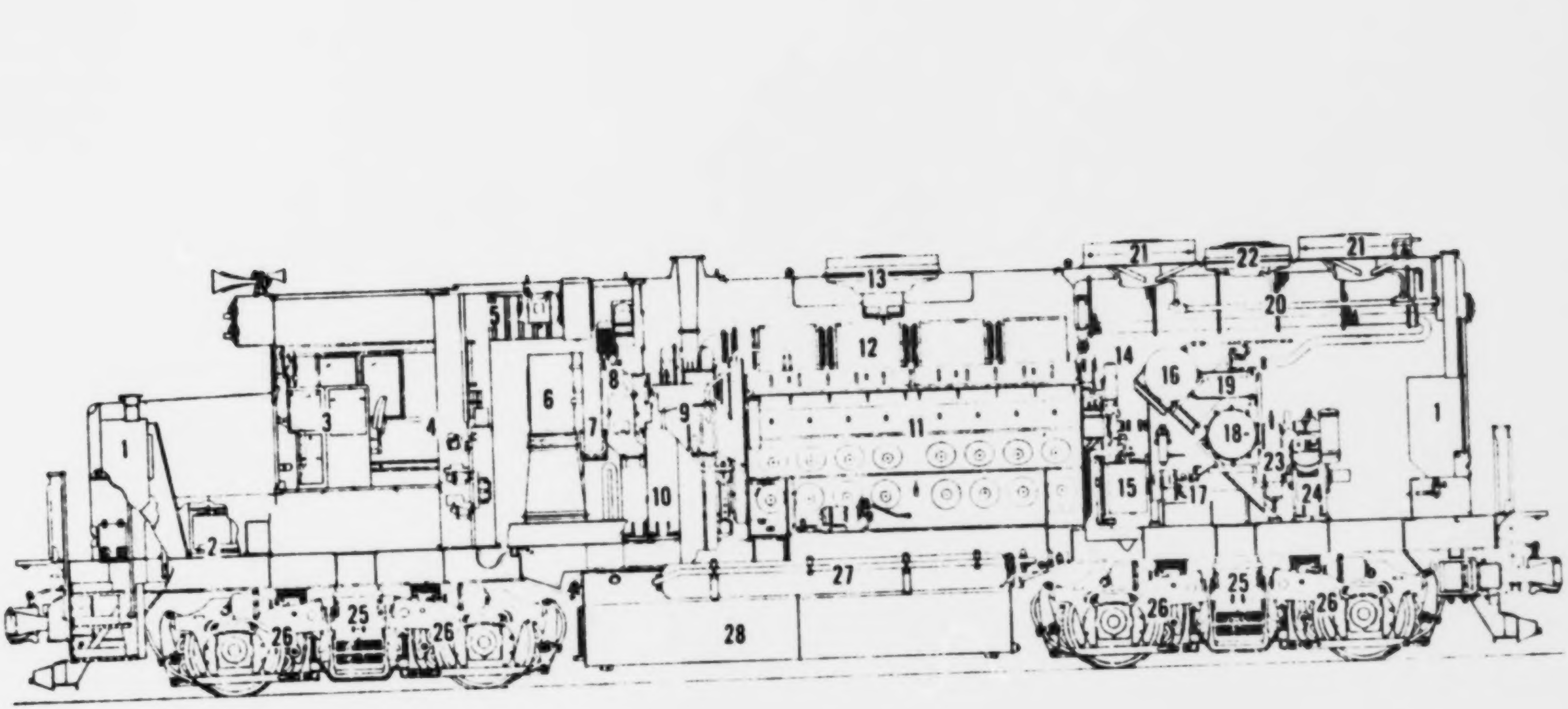
1. Sand Box
2. Battery
3. Loco. Controls
4. Electrical Cabinet
5. Inertial Separator
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Turbocharger
10. Main Generator and Alternator
11. Engine 16-567 D3A
12. Exhaust Manifold
13. Dyn. Brake Fan
14. Governor
15. Lube Oil Strainer Housing
16. Eng. Water Tank
17. Fuel Pump
18. Lube Oil Filter
19. Lube Oil Cooler
20. Radiator
21. 48" Fan and Motor
22. 36" Fan and Motor
23. Fuel Pressure Filter
24. Air Compressor
25. Trucks
26. Traction Motors
27. Main Air Reservoir
28. Fuel Tank

General Arrangement
GP 35



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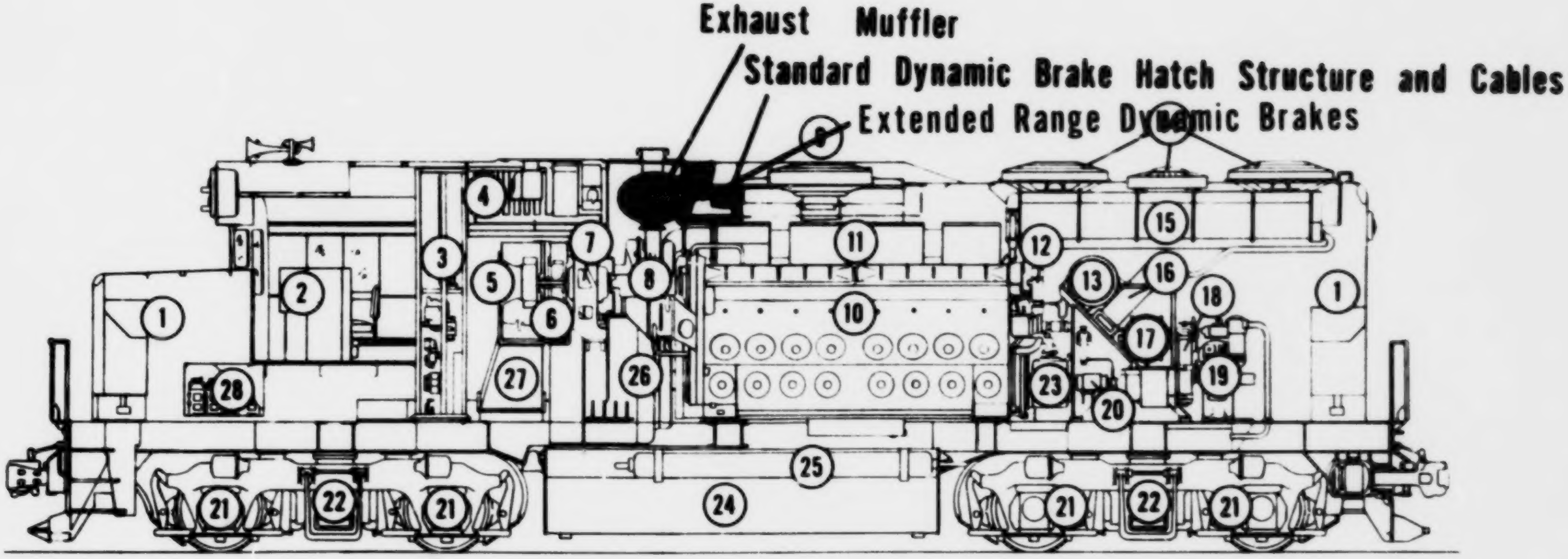
1. Sand Box
2. Battery
3. Loco. Controls
4. Electrical Cabinet
5. Inertial Separator
6. Traction Motor Blower
7. Generator Blower
8. Auxiliary Generator
9. Turbocharger
10. Main Generator and Alternator
11. Engine 16-567 D3A
12. Exhaust Manifold
13. Dyn. Brake Fan
14. Governor
15. Lube Oil Strainer Housing
16. Eng. Water Tank
17. Fuel Pump
18. Lube Oil Filter
19. Lube Oil Cooler
20. Radiator
21. 48" Fan and Motor
22. 36" Fan and Motor
23. Fuel Pressure Filter
24. Air Compressor
25. Trucks
26. Traction Motors
27. Main Air Reservoir
28. Fuel Tank

General Arrangement

GP 35 STANDARD


Exhaust Muffler
Standard Dynamic Brake Hatch Structure and Cables
Extended Range Dynamic Brakes
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1. Sand Box
2. Loco. Controls
3. Electrical Cabinet
4. Dust Filter & Blower Motor
5. Traction Motor Blower
6. Generator Blower
7. Auxiliary Generator
8. Turbocharger
9. Grid Blower Motor
10. D3 Diesel Engine
11. Exhaust Manifold
12. Governor
13. Engine Water Tank
14. Engine Cooling Fans
15. Radiators
16. Lube Oil Cooler
17. Lube Oil Filter
18. Fuel Filter
19. Air Compressor
20. Fuel Pump
21. Traction Motors
22. Truck
23. Lube Oil Strainer
24. Fuel Tank
25. Air Reservoir
26. Main Generator & Alternator
27. Traction Motor Air Duct
28. Batteries

General Arrangement

GP 30

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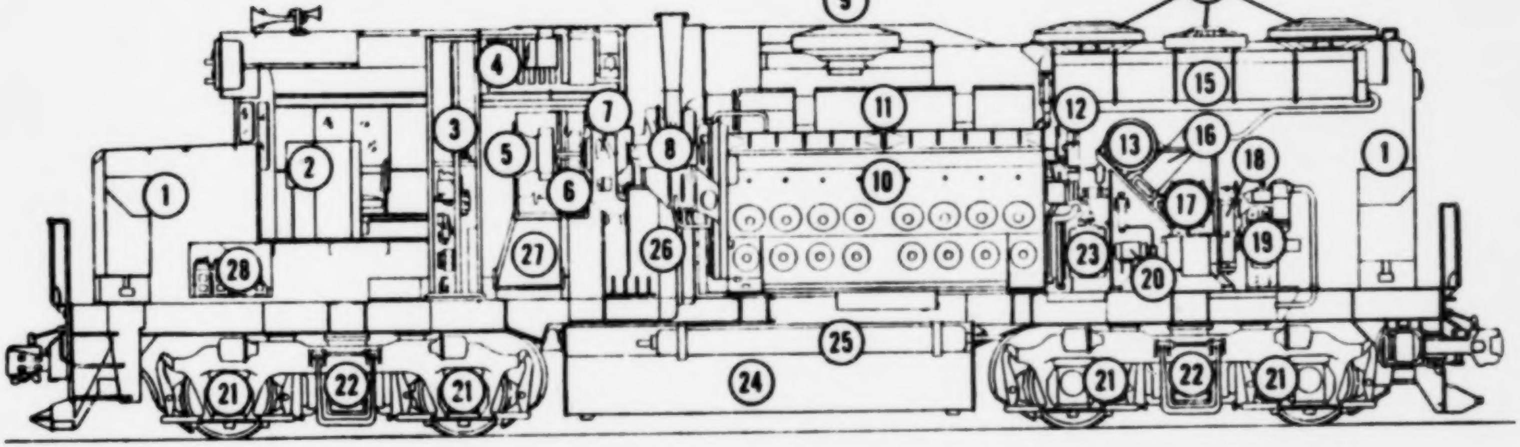
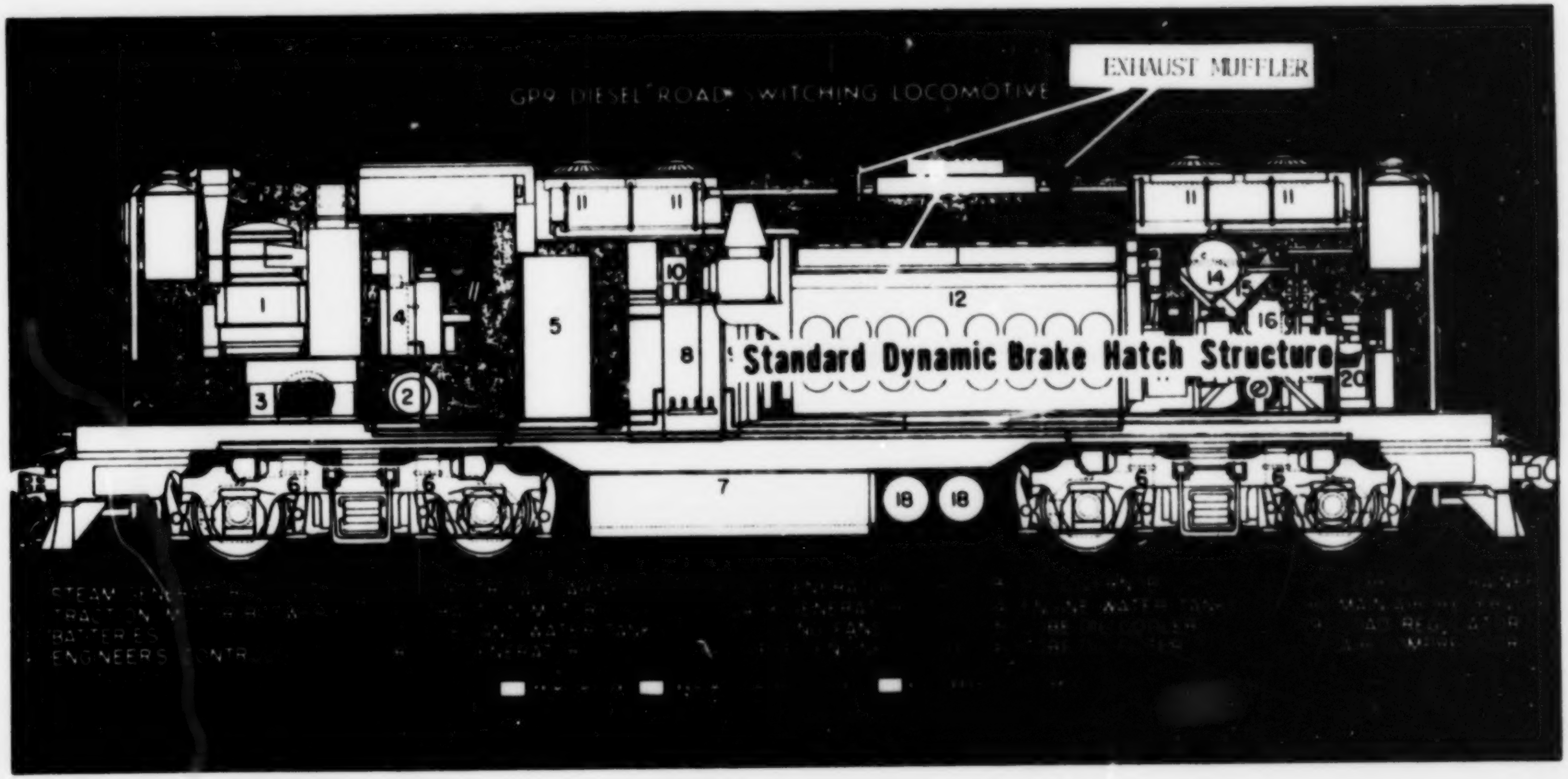


1. Sand Box
2. Loco. Controls
3. Electrical Cabinet
4. Dust Filter & Blower Motor
5. Traction Motor Blower
6. Generator Blower
7. Auxiliary Generator
8. Turbocharger
9. Grid Blower Motor
10. D3 Diesel Engine
11. Exhaust Manifold
12. Governor
13. Engine Water Tank
14. Engine Cooling Fans
15. Radiators
16. Lube Oil Cooler
17. Lube Oil Filter
18. Fuel Filter
19. Air Compressor
20. Fuel Pump
21. Traction Motors
22. Truck
23. Lube Oil Strainer
24. Fuel Tank
25. Air Reservoir
26. Main Generator & Alternator
27. Traction Motor Air Duct
28. Batteries

General Arrangement

GP-30 STANDARD


EXHAUST MUFFLER
GP9 DIESEL ROAD SWITCHING LOCOMOTIVE
Standard Dynamic Brake Hatch Structure
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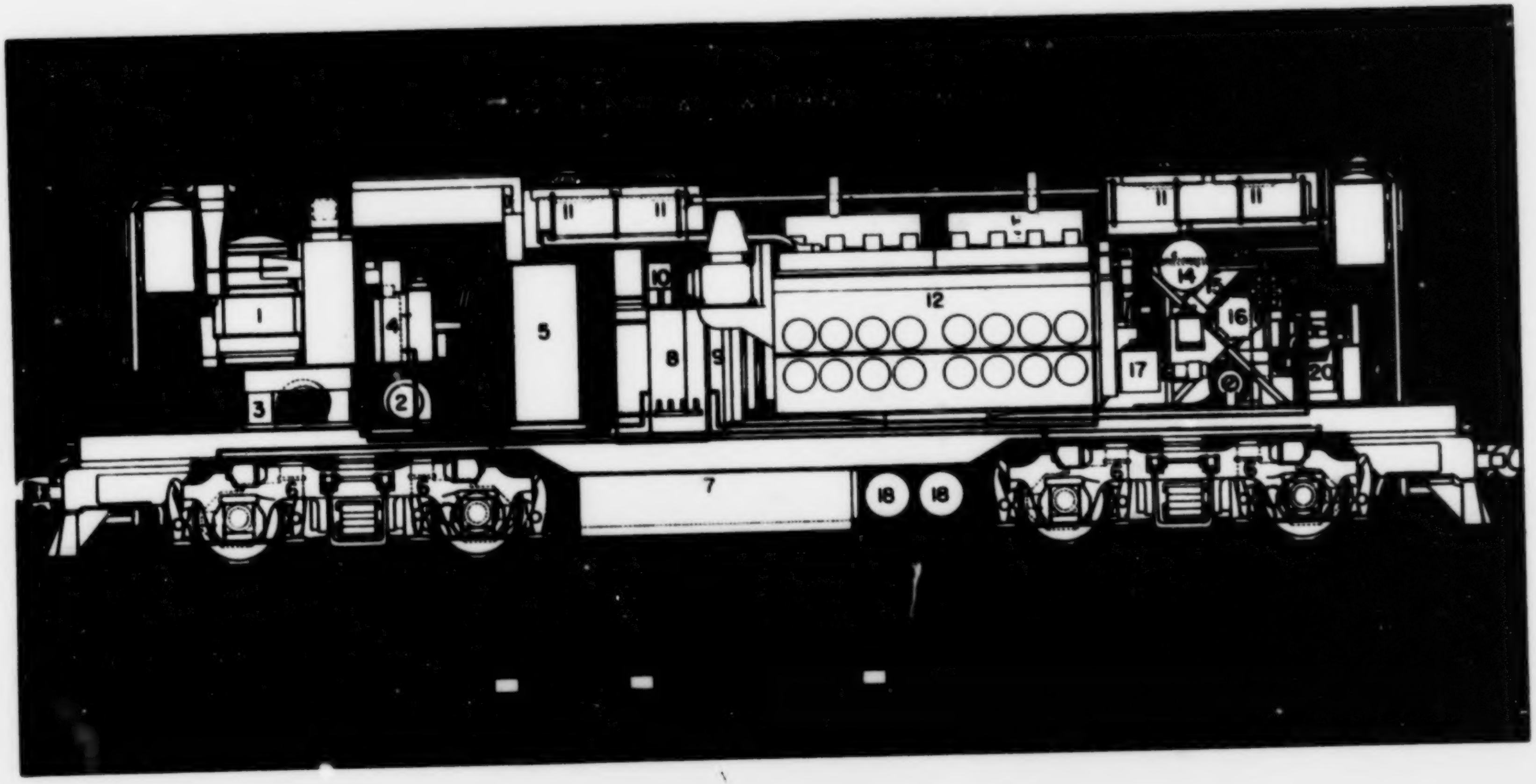
BATTERIES

General Arrangement

GP 7/9/18

MODIFIED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General Arrangement

GP 7/9/18 STANDARD

GENERAL MOTORS CORPORATION
ADDITIONAL COMMENTS TO THE
ENVIRONMENTAL PROTECTION AGENCY
PROPOSED RAILROAD NOISE EMISSION STANDARDS
DOCKET NUMBER ONAC 7201002

DESCRIPTION

The Environmental Protection Agency, Office of Noise Abatement and Control (ONAC), has published proposed standards for sound levels resulting from the operation of locomotives and railroad cars of surface carriers engaged in interstate commerce by railroads. The ONAC has also published a Background Document which explains the basis of, purposes for, and environmental effects of the proposed standards.

To further support General Motors Corporation's response to the Environmental Protection Agency's Proposed Railroad Noise Emission Standards, the following comments are offered as an addendum to the August 15, 1974 Comments of General Motors Corporation With Respect to Proposed Railroad Noise Emission Standards, Docket No. ONAC 7201002.

GENERAL COMMENTARY

General Motors believes that stationary locomotive sound level limits of 93 dBA at any throttle setting and 83 dBA at idle measured at 30 meters effective 270 days from the date of promulgation of the regulations, are reasonable requirements.

General Motors believes that a stationary locomotive sound level limit of 87 dBA at any throttle setting measured at 30 meters and effective four years from the date of promulgation of the regulations, is a technically feasible requirement. It can be achieved on future production locomotives by the application of mufflers and necessary structural changes to accommodate the muffler.

The following is a summary of General Motors additional comments to the proposed standards:

1. Exhaust noise is not the major contributor to overall locomotive idle noise measured at 100 feet; and therefore, the addition of a locomotive exhaust muffler will not reduce idle locomotive noise by 6 dBA from 73 dBA to 67 dBA as the EPA proposed railroad noise emission regulation requires.

2. General Motors does agree that full power locomotive noise is exhaust noise dominant and the addition of exhaust mufflers will permit the achievement of the proposed regulation of 87 dBA at 100 feet effective four years from the date of promulgation.

1. FULL POWER OVERALL LOCOMOTIVE EXHAUST NOISE AT 100 FEET

To demonstrate that full power overall locomotive noise at 100 feet is controlled by the exhaust noise level, consider Figures 1, 2, and 3. The graphs compare A-weighted octave band sound levels measured at 3 feet from the exhaust outlet and at 100 feet from the side of the locomotive during full power (eighth throttle) operation (radiator cooling fans not operating to eliminate their influence) for three present production road locomotives, SD40-2, GP39-2, and GP38-2, respectively. Inspection of these plots shows that a good correlation for all three locomotives can be made between the full power exhaust noise spectrum at three feet and the overall locomotive noise spectrum measured at 100 feet when a 30 dB attenuation factor for hemispherical sound spreading is used to correct for the increased distance. For most points, the measured octave band level at 100 feet is less than that predicted using the 30 dB attenuation factor indicating excess attenuation not accounted for. When the measured octave band level is greater than that predicted, structurally-radiated locomotive noise is contributing to the overall locomotive noise.

Extending this correlation to analyze idle locomotive overall noise demonstrates that exhaust noise is not the major contributor at idle. Figures 4, 5, and 6 correspond to figures 1, 2, and 3 respectively, but compare idle exhaust noise level at three feet with idle overall locomotive noise at 100 feet for the same three locomotives. It becomes immediately apparent upon applying the 30 dB attenuation factor to the idle exhaust noise spectrum that the correlation observed between exhaust and overall noise at full power does not exist at idle. For all three locomotives, which include both turbocharged and roots blown engines, the octave bands controlling the overall A-weighted locomotive sound level at 100 feet are not exhaust noise dominated and are, in fact, controlled by structurally-radiated noise. Therefore, it is technically not possible to reduce idle overall locomotive noise with the application of an exhaust muffler.

2. STATIONARY LOCOMOTIVE IDLE NOISE EMISSION DATA - TABLE 4-2 IN THE BACKGROUND DOCUMENT

General Motors evaluation of the stationary locomotive idle noise emission data presented in Table 4-2 in the Background Document is as follows:

Considering only General Motors locomotives and only those measurements actually taken at 100 feet, * the mean value of the locomotive idle noise level measurements is 68.4 dBA and the standard deviation is 1.9 dBA. These values agree well with General Motors data which indicates a mean of 68.2 dBA and standard deviation of 1.7 dBA for present production locomotive models tested. Based on these means and standard deviations, approximately 74% of all General Motors locomotives exceed the proposed level of 67 dBA at 100 feet at idle.

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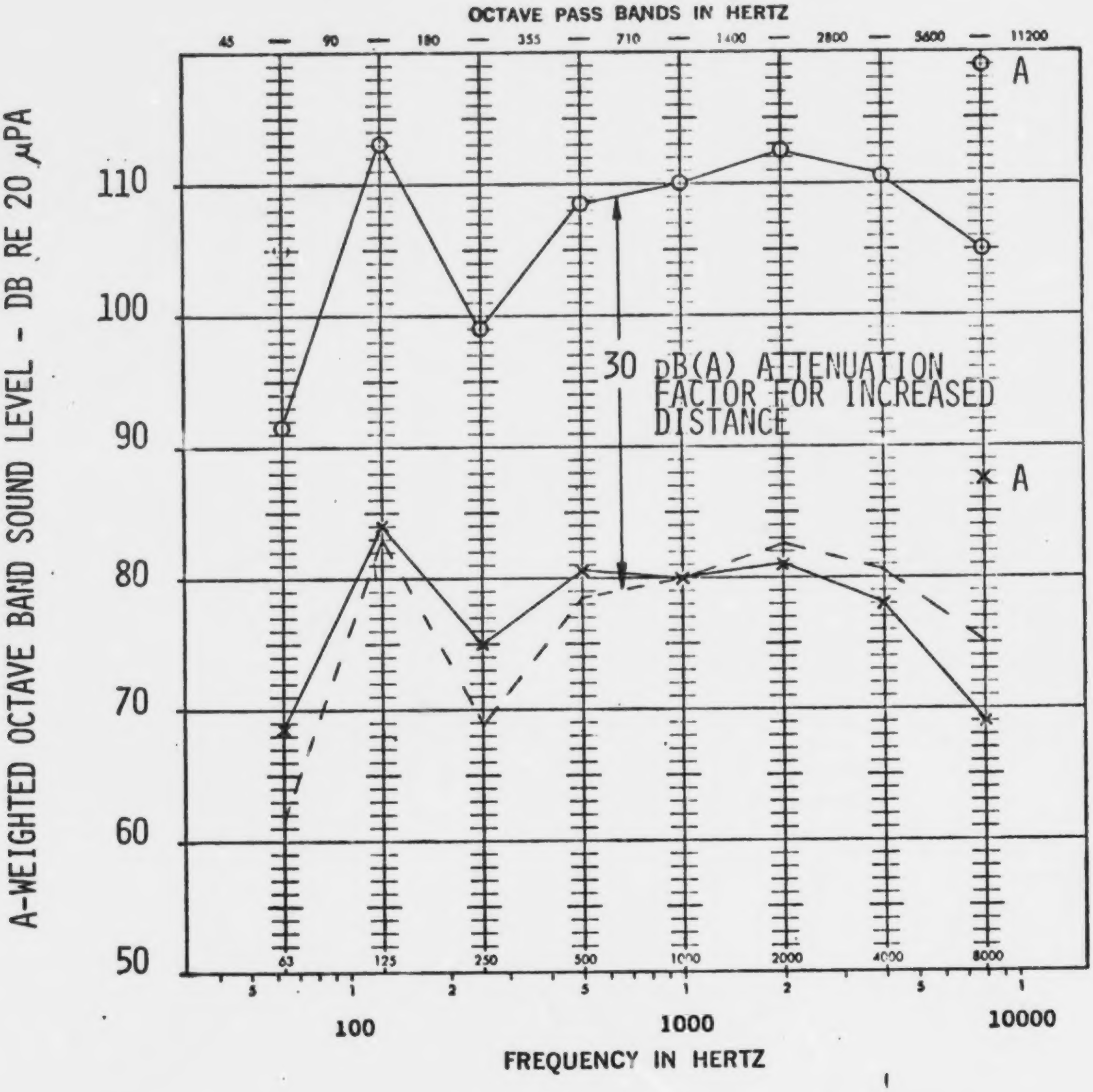
*Refer to COMMENTS, Page 5, Item 2.

CONCLUSIONS

In summary, it has been demonstrated that application of exhaust mufflers will not allow locomotives to meet the proposed idle noise level requirement of 67 dBA at 100 feet. Further, 74% of all GM locomotives, which account for approximately 75% of all locomotives presently in service, currently exceed the proposed noise level of 67 dBA. Therefore, taking into consideration available technology, cost of compliance and the intent of the proposed regulation to insure 100% idle noise level compliance, it is General Motors opinion that the idle noise level requirement should be maintained at 73 dBA.

SD40-2 LOCOMOTIVE

TURBOCHARGED - 3,000 HP



8TH THROTTLE, FULL LOAD

o—o 3 FEET FROM EXHAUST OUTLET

×—× 100 FEET FROM SIDE OF LOCOMOTIVE, NO COOLING FANS OPERATING

FIGURE 1

GP39-2 LOCOMOTIVE

TURBOCHARGED - 2,300 HP

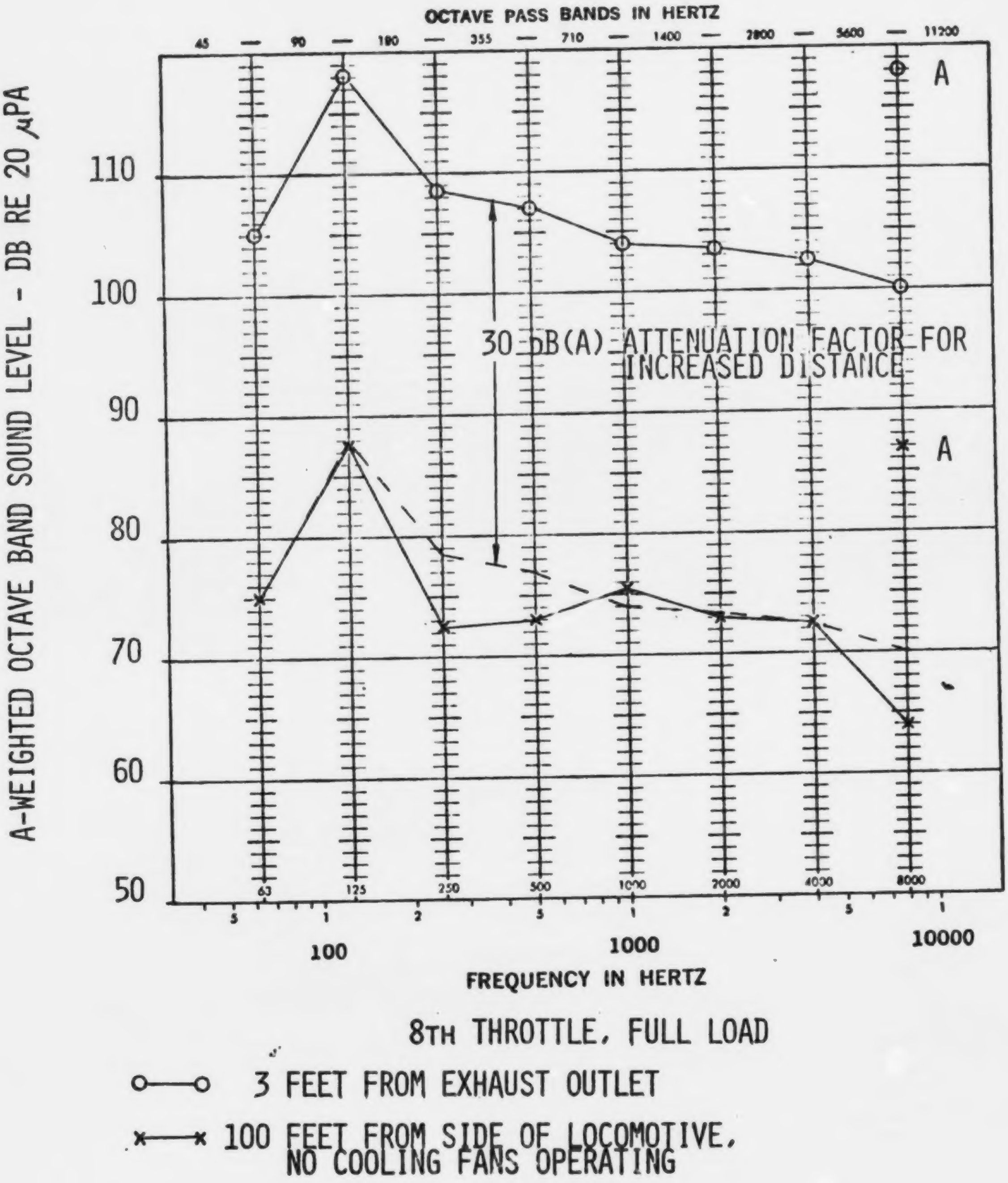
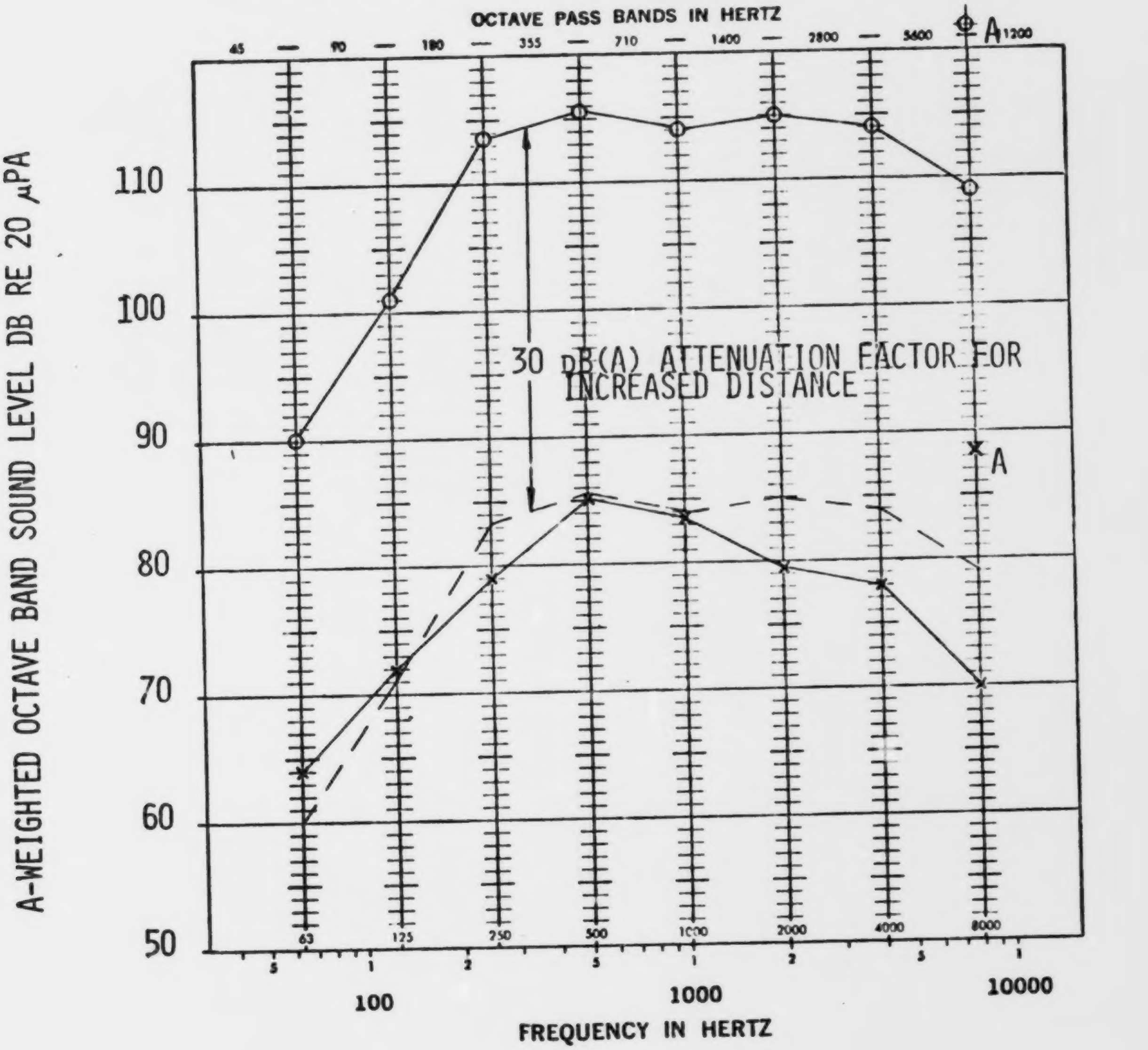


FIGURE 2

GP38-2

ROOTS BLOWN - 2,000 HP LOCOMOTIVE
EQUIPPED WITH PRODUCTION SPARK ARRESTER EXHAUST MANIFOLDS



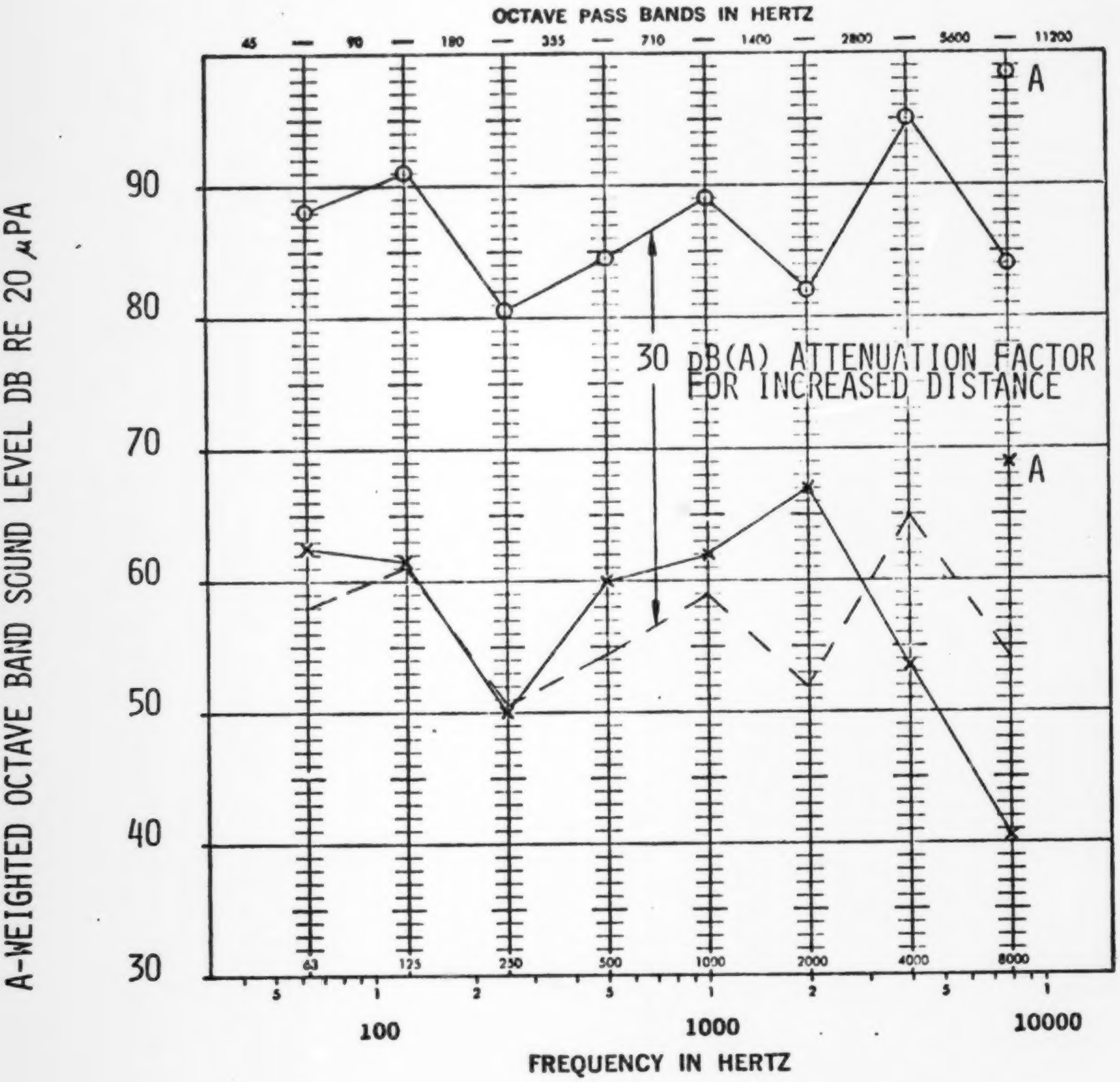
8TH THROTTLE, FULL LOAD

o—o 3 FEET FROM EXHAUST OUTLET

x—x 100 FEET FROM SIDE OF LOCOMOTIVE,
NO COOLING FANS OPERATING.

FIGURE 3

SD40-2 LOCOMOTIVE



IDLE

o—o 3 FEET FROM EXHAUST OUTLET

x—x 100 FEET FROM SIDE OF LOCOMOTIVE, NO COOLING FANS OPERATING.

FIGURE 4

GP39-2 LOCOMOTIVE

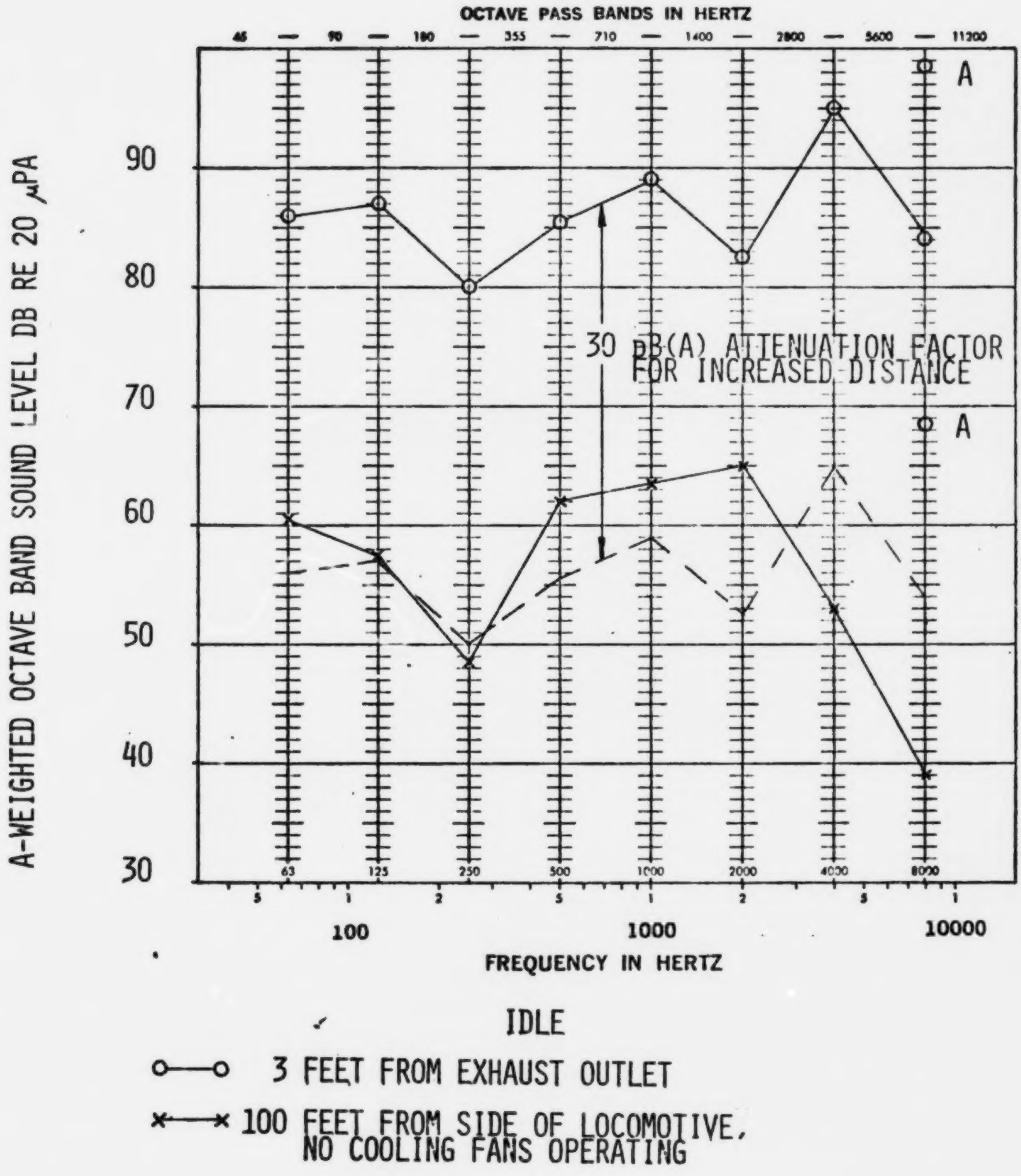


FIGURE 5

GP38-2 LOCOMOTIVE

PRODUCTION SPARK ARRESTER EXHAUST MANIFOLDS

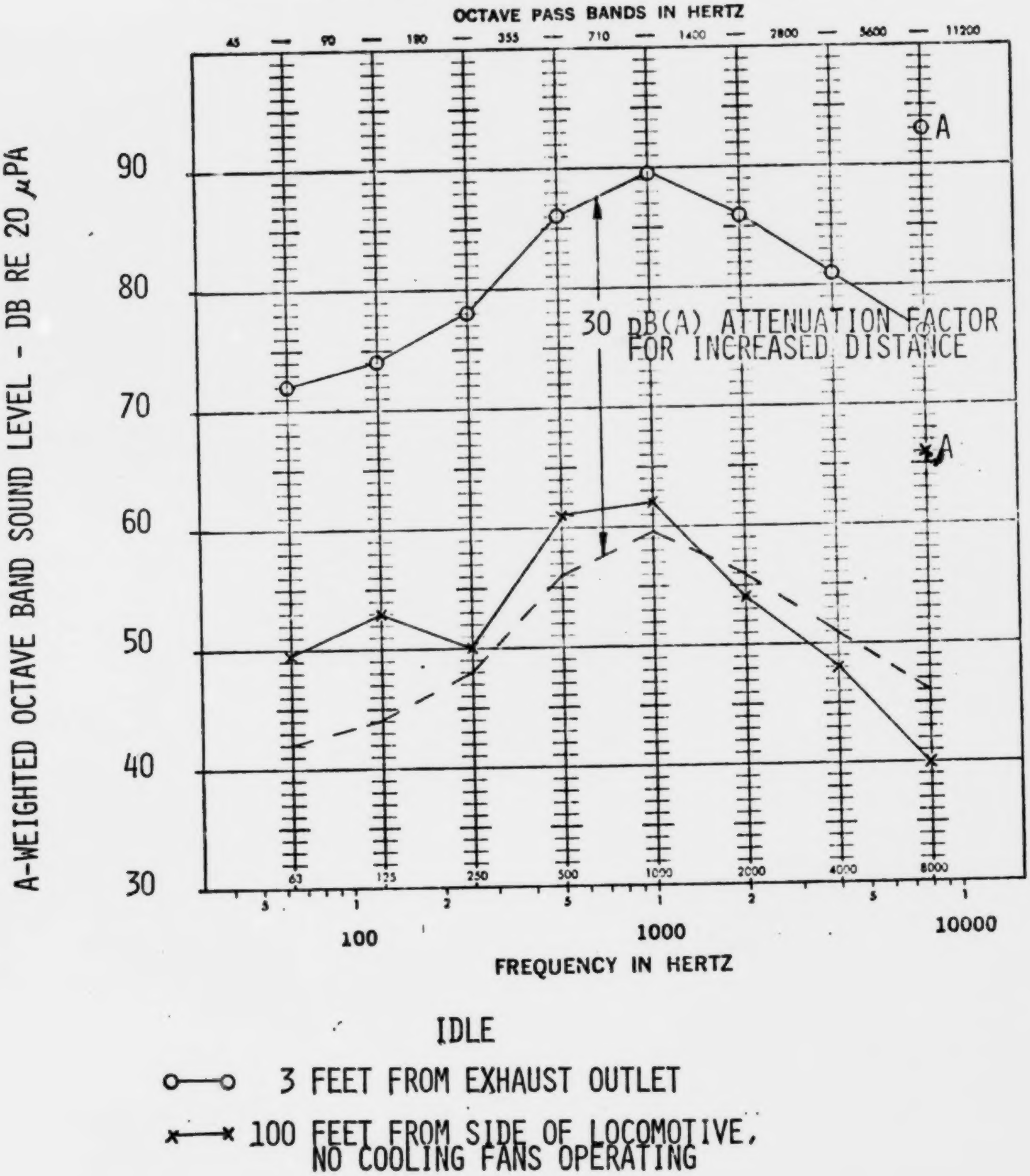


FIGURE 6

3. MUFFLER DESIGN FOR LOCOMOTIVES

This section outlines the results of a study undertaken to design mufflers for several types of diesel-electric locomotives. The design process takes into account

- noise control requirements,
- maximum allowed backpressures,
- chemically contaminated exhaust flow, and
- maximum available space.

Conceptual designs are presented for four locomotives which represent all of the types in service. The models analyzed are

- EMD GP-35 (turbocharged),
- EMD GP-40 (turbocharged),
- EMD GP-38 (Roots-blown),
- GE U-series (turbocharged).

Design Goals and Techniques

The aim of the project was to design mufflers which would reduce locomotive exhaust noise levels by 10 dBA, yet fit within the presently available space. Muffler-induced backpressure was constrained to be within 5-in. H_2O for turbocharged engines and 21-in. H_2O for nonturbocharged engines. In addition, sound absorptive treatments, such as steel wool packing or porous plates, were excluded from consideration because it is not known how they would be affected by dirty exhaust gases.

Given these constraints, it was determined that best performance could probably be achieved using mufflers of the reactive type. Reactive mufflers obtain their effectiveness from abrupt changes in the cross-sectional area of the exhaust pipe, which tend to reflect sound back toward the source. Unfortunately, these discontinuities also tend to generate areas of flow separation, which increase the flow resistance through the muffler and, hence, the backpressure.

A compromise between attenuation performance and backpressure was therefore obtained by smoothing the sharp corners at the transition regions. This smoothing tended to decrease attenuation and backpressure, bringing the latter within allowable limits while still providing 10-dBA or more noise reduction. In addition, the exit pipe was shaped into a Venturi tube, a configuration which improves attenuation via a reduction in pipe cross-sectional area. A schematic of the resulting design, designated Type A, is shown in figure 3-1. Figure 3-2 shows two alternate configurations that were also studied. Types B and C lack the Venturi tube; Type C, however, contains an internal baffle. A fourth alternative studied was to increase the volume of the exhaust manifold; this design is discussed below in the case of the Roots-blown locomotive.

The effectiveness of a muffler in reducing noise depends on how well the muffler's insertion loss spectrum (which represents noise reduction as a function of frequency) is matched to the noise spectrum of the source. If the muffler's effectiveness is concentrated in frequencies where little noise is being generated, little benefit will result. Part of the design process therefore consists of varying the muffler's shape and volume to obtain optimum noise reduction in the frequencies where the most noise is being generated. In this study, the exhaust noise spectrum shown in figure 3-3 was used as a reference for muffler design. The spectrum shown is that of a 12-cylinder, 2000-hp engine on an Alco 250 locomotive. Spectra for other engines may have higher or lower overall levels, and some of the details of the spectral shape may vary from unit to unit, but the overall shape will be fairly constant for most engines.

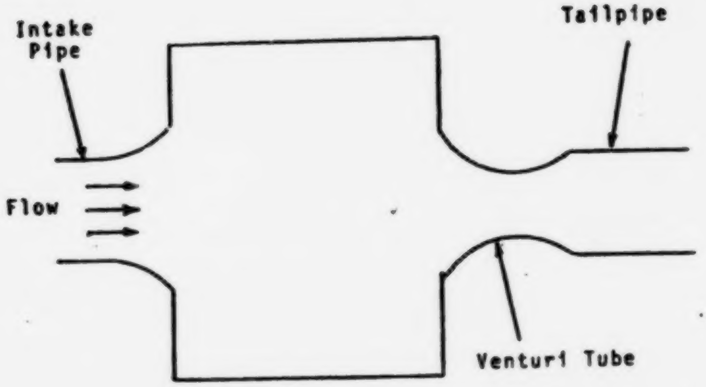

Intake Pipe
Tailpipe
Flow
Venturi Tube

FIGURE 3-1. SCHEMATIC VIEW OF TYPE A MUFFLER.

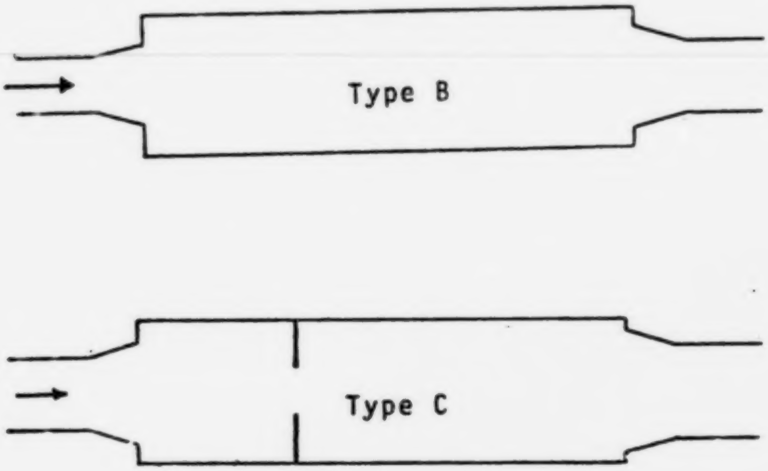

Type B
Type C

FIGURE 3-2. SCHEMATIC VIEW OF TYPES B AND C MUFFLERS.

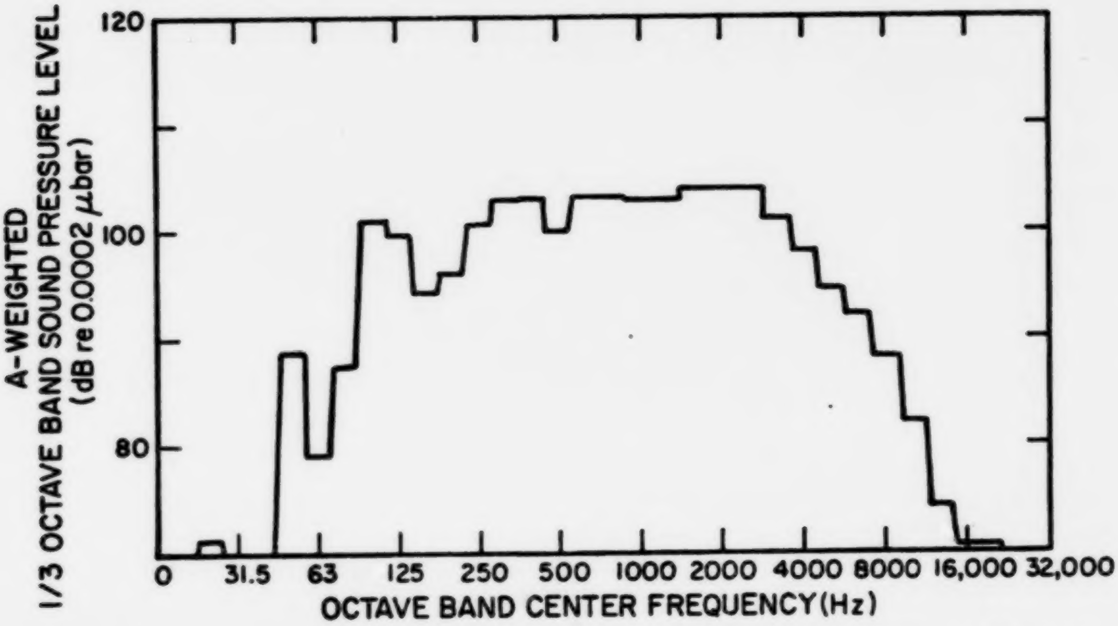


FIGURE 3-3. TYPICAL LOCOMOTIVE EXHAUST NOISE SPECTRUM MEASURED AT 2.5 FT FROM OUTLET.

The muffler design procedure was to select, from among the four described, a general muffler type having dimensions somewhat smaller than the known volume available inside the locomotives. The specific dimensions and the details of inlet and outlet design were then systematically varied, and backpressure and overall attenuation were computed for each trial configuration. This process was continued until a configuration was found that satisfied both noise reduction and backpressure constraints. Performance was explicitly computed at throttle 8 only; performance at idle is discussed later.

Backpressure and attenuation performance were computed using a proprietary BBN computer model. To demonstrate the validity of this model, we predicted the attenuation performance of the EMD-designed Universal Silencer muffler and compared its actual performance, as obtained from EMD measurements. The EMD data for exhaust noise levels with and without the Universal Silencer muffler are shown in figure 3-4. Subtracting the two curves gives the muffler insertion loss, as shown by the dashed line in figure 3-5. The BBN-predicted insertion loss is shown by the solid curve in figure 3-5. The correspondence between the prediction and the measurement is good except in the 200-Hz and 250-Hz bands. These discrepancies are probably caused by some approximations that were made in entering the dimensions of the muffler into the computer. It is clear, however, that the program provides a reasonable indication of a muffler's performance.

Results

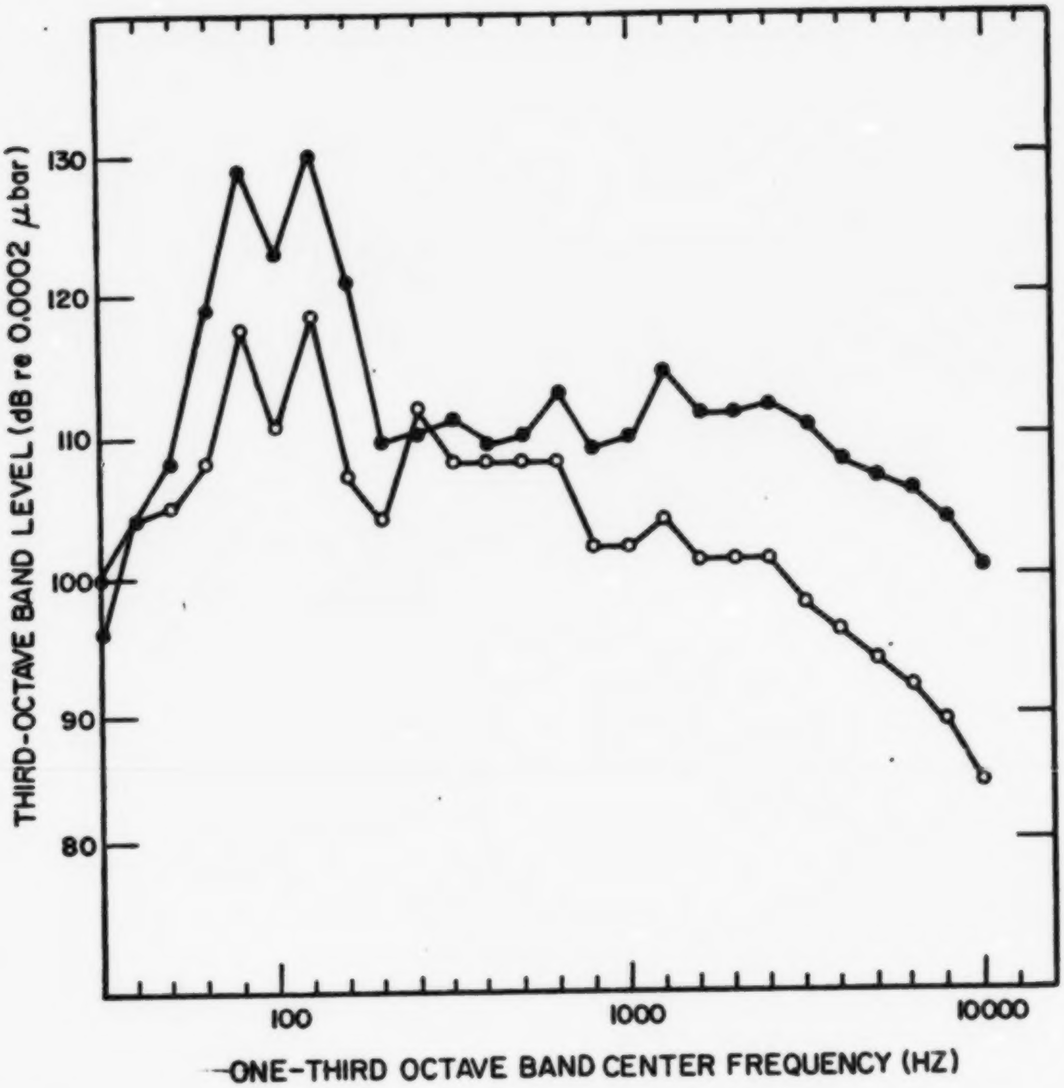
We now describe the final muffler designs and their predicted performance for the four locomotives listed at the beginning of this section.

EMD GP-35. The space available on an EMD GP-35 equipped with standard dynamic brakes is a volume 68 in. long (parallel to the axis of the locomotive) by 48 in. wide by 21 in. high. The dimensions of the turbocharger outlet are 7 in. by 30 in. (Source: Measurement by M. Rudd at Morrison-Knudsen Co., Inc., Boise, Idaho, 26 September 1974.) The muffler designed to fit this space (figure 3-6) is a Type A muffler with an inlet cross section of 7 in. by 30 in., a smoothed transition region into an expansion chamber having a cross section of 68 in. by 48 in., and a Venturi-tube outlet with a minimum cross section of 4.4 in. by 30 in. The detailed dimensions are given in Appendix A. The GP-35 muffler is estimated to provide 10 dB of exhaust noise attenuation while imposing an additional 4.5-in. H_2O of backpressure.

EMD GP-40. The space presently available in a GP-40 with standard dynamic brakes* is a volume above the turbocharger of

---

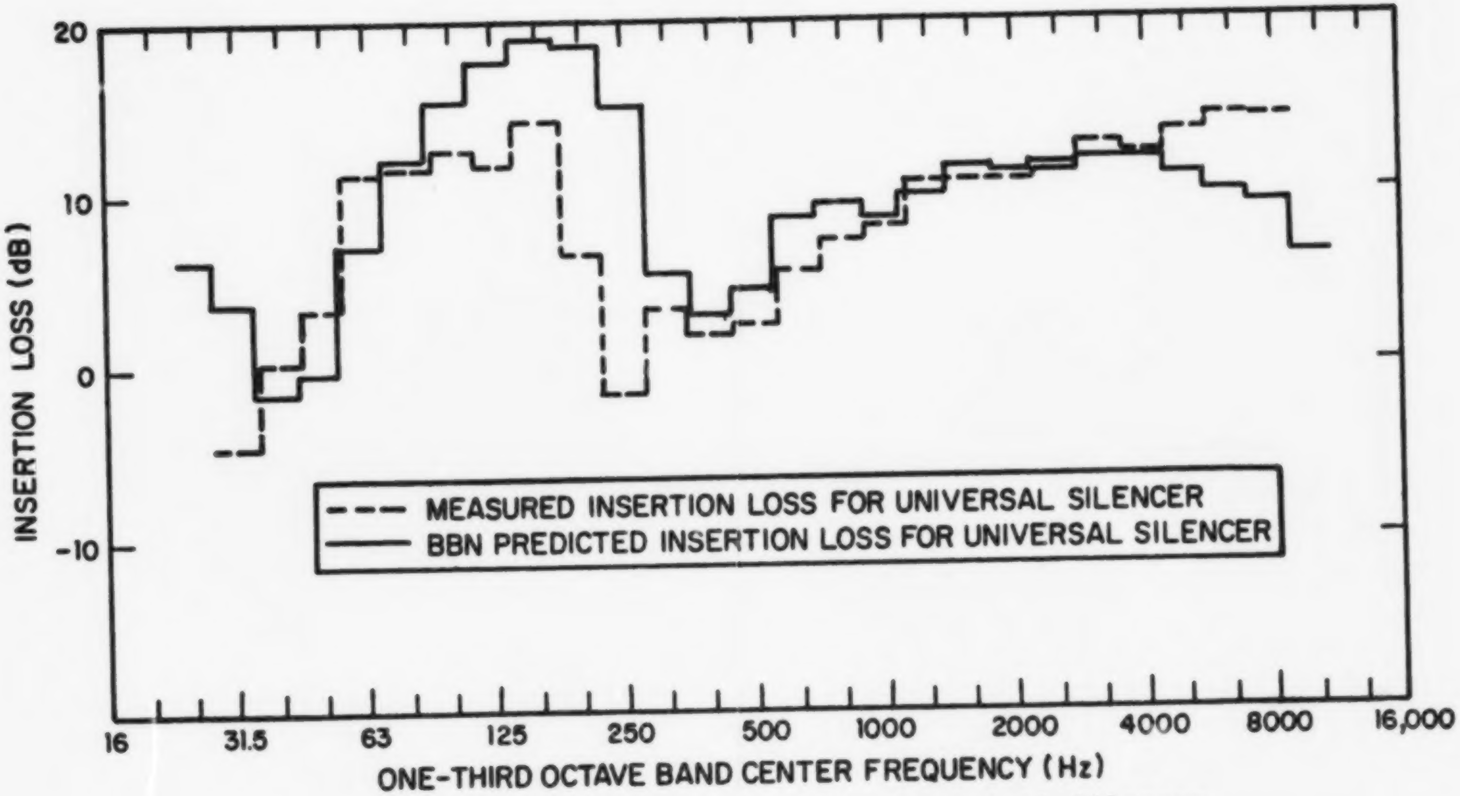
*This feature was present on 74 percent of the 1202 GP-40s produced; see EMD statement of 1 November 1974.



●——● Production Model

○——○ With Universal Silencer Exhaust Muffler Measurements at 3 ft from Exhaust Outlet, Locomotive Stationary Under Rated Engine Speed and Load Conditions.

FIGURE 3-4. MEASUREMENTS OF EXHAUST NOISE OF AN EMD SD45-2, WITH AND WITHOUT UNIVERSAL SILENCER EXHAUST MUFFLER (Source: EMD, 1973).



--- Measured Insertion Loss for Universal Silencer
—— BBN Predicted Insertion Loss for Universal Silencer

FIGURE 3-5. COMPARISON OF MEASURED ATTENUATION FOR UNIVERSAL SILENCER MUFFLER WITH BBN PREDICTION.

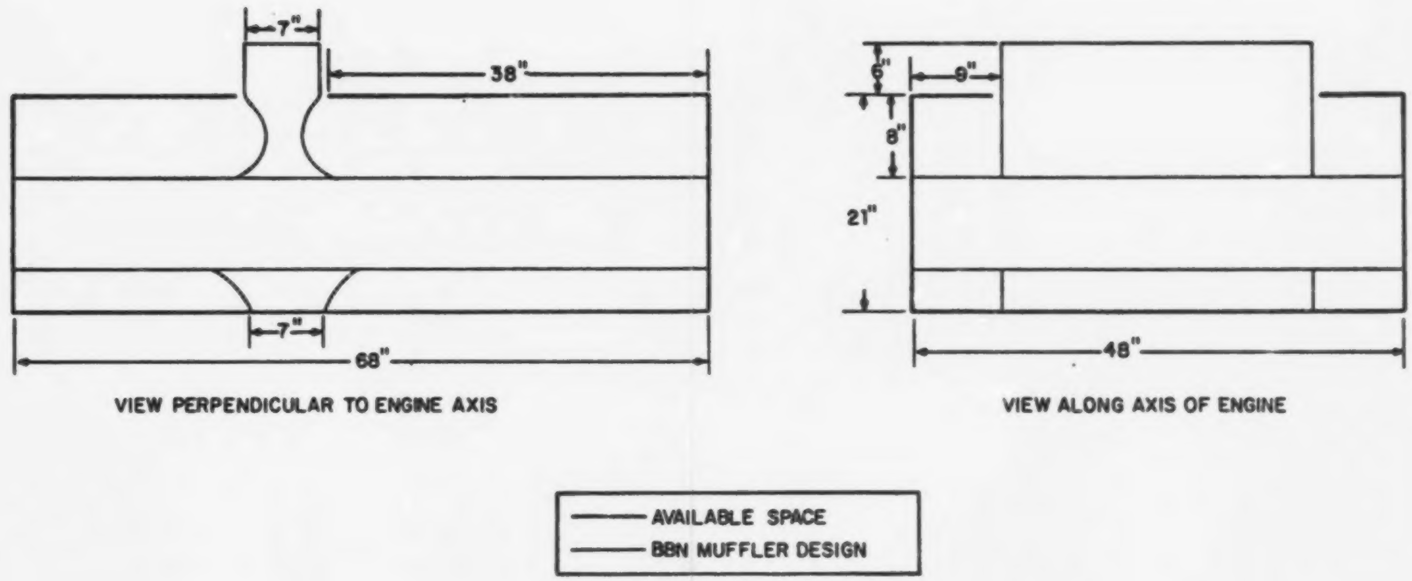

7"
38"
7"
68"
VIEW PERPENDICULAR TO ENGINE AXIS
6"
9"
8"
21"
48"
VIEW ALONG AXIS OF ENGINE
AVAILABLE SPACE
BBN MUFFLER DESIGN

FIGURE 3-6. AVAILABLE SPACE (SOLID LINE) AND MUFFLER PROFILE (DASHED LINE) FOR GP-35.

approximately 65 in. by 46 in. by 20 in. (Source: EMD presentation to AAR, 8 August 1973.) The muffler designed to fit this space is shown in figure 3-7. It is a Type A muffler having an inlet cross section of 7 in. by 30 in., an expansion chamber with a cross section of 35 in. by 65 in., and a Venturi-tube outlet with a minimum cross section of 5.3 in. The detailed dimensions are given in Appendix A. The GP-40 muffler is estimated to provide 12 dBA of exhaust noise reduction, while imposing an additional 3-in. H_2O of backpressure.

Figure 3-7 also shows the profile of the EMD-designed Universal Silencer muffler. We see that this muffler is higher than the allowable volume, and the stack outlet is displaced from its original position. The Universal Silencer design therefore requires numerous modifications to the turbocharger removal hatch (AAR, R013). These modifications are avoided in the BBN design.

EMD GP-38. The above engines were turbocharged, so that the exhaust stream was collected into a single pipe to which a single muffler could be applied. This is not the case with the GP-38, which is Roots-blown; the exhaust manifold consists of four in-line cylindrical collectors, each receiving gas from four cylinders. The collectors are connected to form two groups of two; each group then has one exhaust pipe of approximately 5-in. by 15-in. cross section exiting through the roof. To install a single muffler, as in the above cases, would entail grouping the four collectors into a single manifold/exhaust line and placing a muffler on the exhaust line. Figure 3-8 is a sketch of such an arrangement. (Source: EMD presentation to AAR, 8 August 1973.) In general, little room is available for a muffler, especially in those engines having three cooling fans; the third fan generally takes up the space shown for the muffler in figure 3-7.

An alternate approach is to retain the existing exhaust manifold design, but to enlarge the collectors so as to provide additional attenuation. The existing collectors are approximately

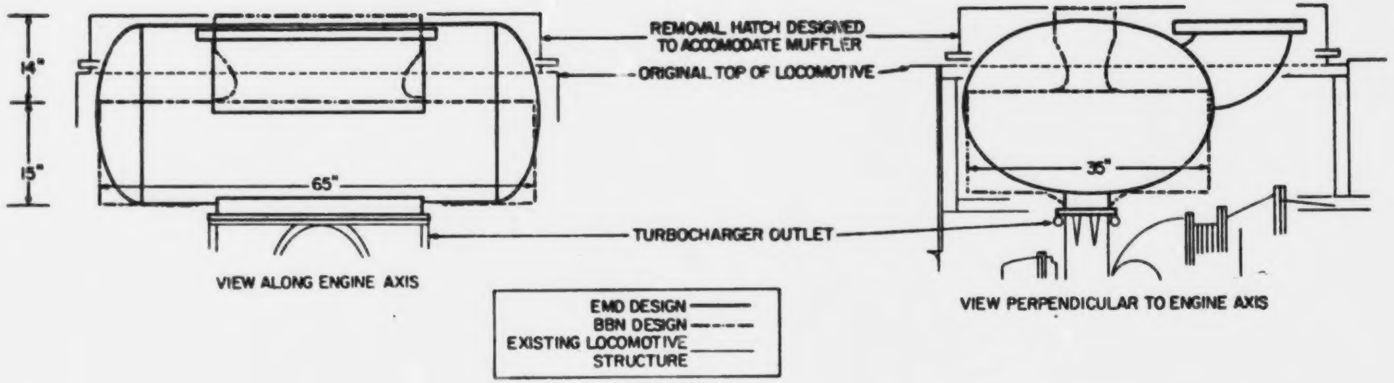

14"
15"
65"
VIEW ALONG ENGINE AXIS
REMOVAL HATCH DESIGNED TO ACCOMODATE MUFFLER
ORIGINAL TOP OF LOCOMOTIVE
TURBOCHARGER OUTLET
35"
VIEW PERPENDICULAR TO ENGINE AXIS
EMD DESIGN
BBN DESIGN
EXISTING LOCOMOTIVE STRUCTURE

FIGURE 3-7. AVAILABLE SPACE AND MUFFLER DESIGNS FOR EMP GP-40

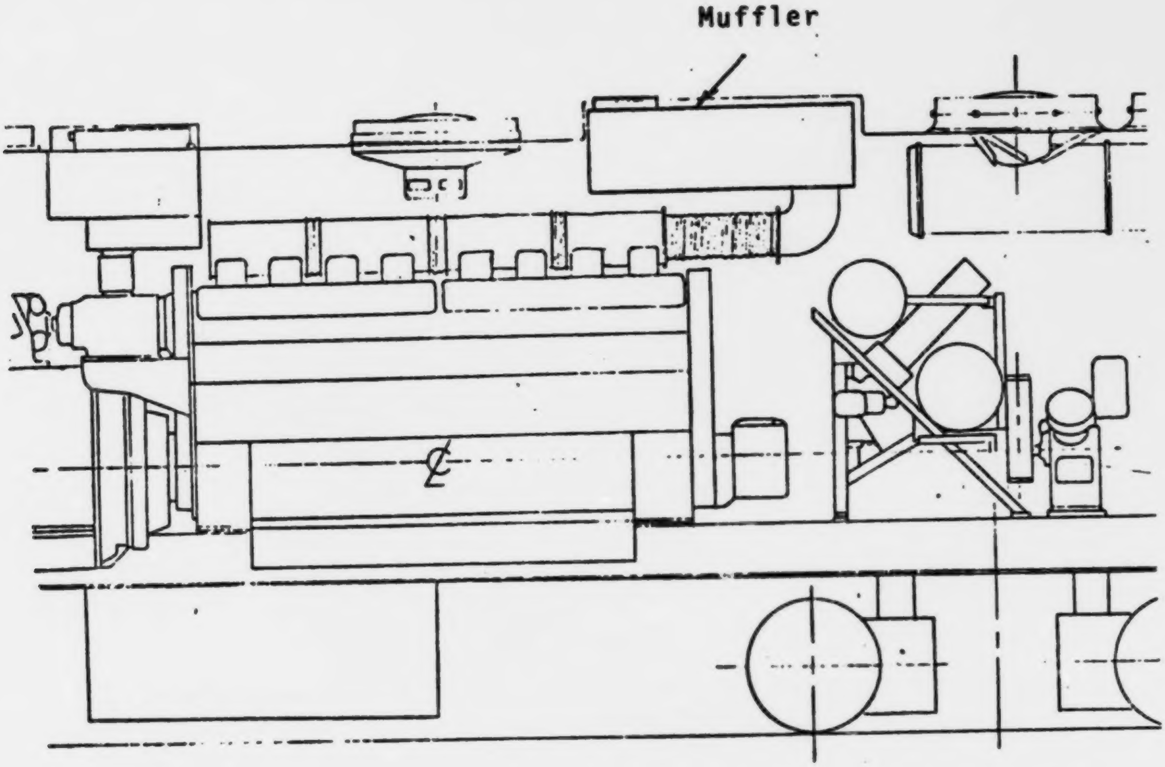


FIGURE 3-8. EMD CONCEPT FOR INSTALLING EXHAUST MUFFLER ON A ROOTS-BLOWN LOCOMOTIVE.

15 in. in diameter; there are roughly an additional 12 in. of space available between the tops of the collectors and the bottom of the resistor grid fan. (Sources: Drawings in EMD presentation to AAR, 8 August 1973.) The BBN-designed manifold replaces each pair of 15-in. diameter collectors with a single expansion chamber having an elliptical cross section, the minor (vertical) axis of which is 26 in. and the major (horizontal) axis, 30 in. A sketch of the two arrangements is shown in figure 3-9. The new manifold is estimated to give 5-dB attenuation more than the old one, with an additional backpressure penalty of about 0.5-in. H_2O. Detailed dimension and performance estimates are given in Appendix A.

This design preserves all existing components except the manifold cylinders themselves. If further attenuation is required, a still larger manifold could be installed by taking advantage of the existing clearance between the bottom of the existing manifold and the top of the engine.

GE U-Series. The GE locomotives do not have fans or other equipment above the engine; this space is therefore available for muffler installation. On all the locomotives, the vertical space between the top of the engine and the maximum height limit is 20 in.; the length of this space varies from model to model. For our computations, we have used an available volume 16 in. high by 36 in. wide by 160 in. long; the length corresponds to the U25, U33, and U36 models. (Source: GE presentation to AAR, 8 August 1973.) The available space and the muffler designed to fit it are shown in the plan in figure 3-10. The muffler is a Type C, having an expansion chamber with a cross section of 16 in. by 36 in., which is separated into two segments by a plane baffle having an open area of 300 in. The detailed dimensions and insertion loss are given in Appendix A. This muffler design will give approximately 10 dBA of exhaust noise reduction with a backpressure penalty of 1.5-in. H_2O. It should be noted that this

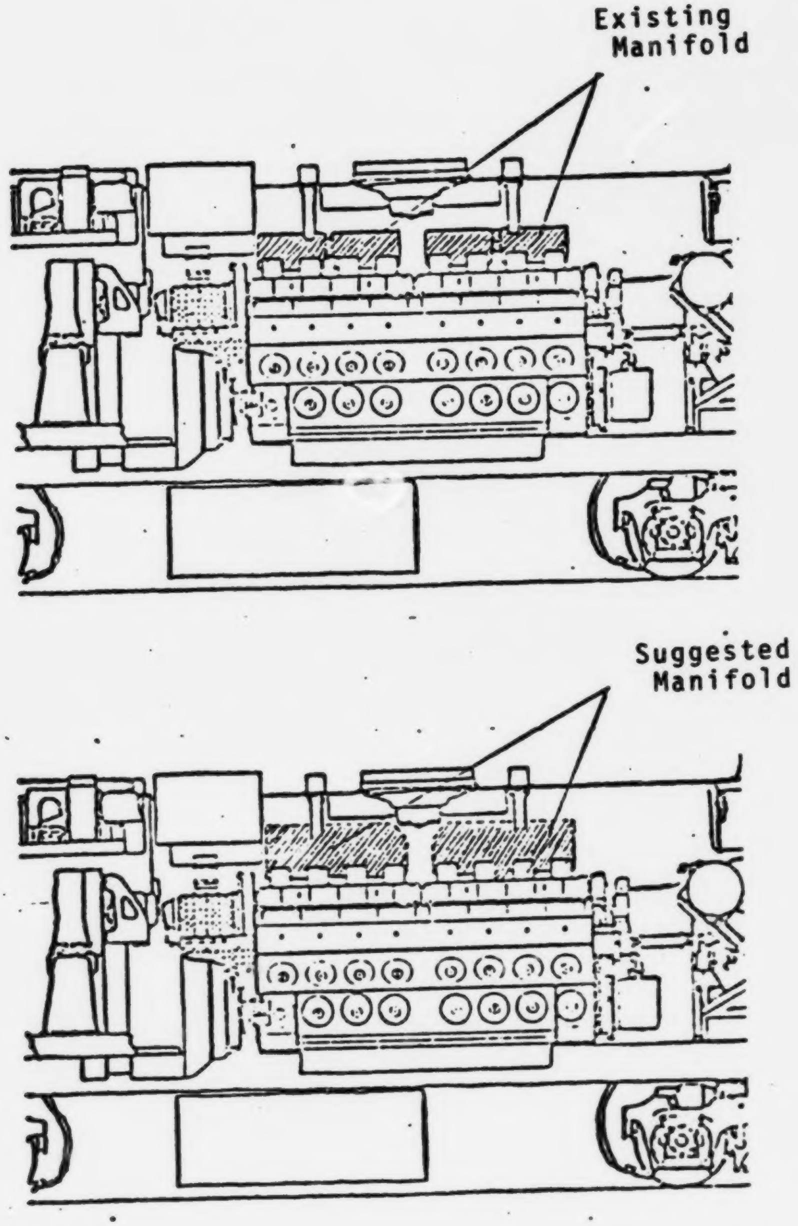

Existing Manifold
Suggested Manifold

FIGURE 3-9. MANIFOLD MUFFLER DESIGN FOR GM GP-38

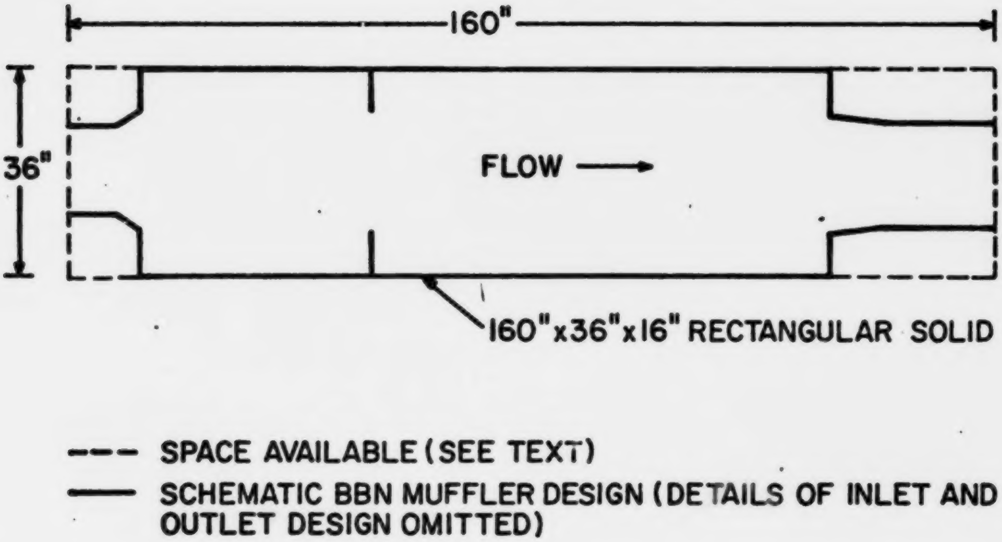

160"
36"
FLOW
160"x36"x16" RECTANGULAR SOLID
--- SPACE AVAILABLE (SEE TEXT)
— SCHEMATIC BBN MUFFLER DESIGN (DETAILS OF INLET AND OUTLET DESIGN OMITTED)

FIGURE 3-10. PLAN VIEW OF AVAILABLE SPACE AND MUFFLER OUTLINE FOR GE U25, U33, AND U36 LOCOMOTIVES

muffler would protrude through the roof and thus would require some car body modifications.

Summary

Table 3-1 summarizes the attenuation and backpressure performance of the four muffler designs described above. With the exception of the GP-38, all the designs met their goals. The GP-38 manifold muffler provided only 5-dBA attenuation, but the design did not take advantage of all the available space.

TABLE 3-1

ATTENUATION AND BACKPRESSURE PERFORMANCE OF CONCEPTUAL MUFFLER DESIGNS

Locomotive	Type	Reduction in A-Weighted Exhaust Noise Level-dB	Increase in Backpressure — in. H_2O
EMD GP-35	TC	10	4.5
EMD GP-40	TC	12	3.0
EMD GP-38	RB	5	0.5
GE U-25, 33, 36	TC	10	1.5

The attenuations shown apply at full throttle. Attenuation at idle was not computed with the model, but was estimated by hand calculations. The estimate indicated that a muffler which provides 20-dBA attenuation at full throttle will provide 5- to 6-dBA attenuation at idle.

This development shows that it is possible to design effective locomotive mufflers to meet present volume and backpressure constraints. The preceding designs are still conceptual. They would need to be developed further, refined, and tested before they could be implemented on a large scale, but that process does not appear to present any insuperable problems.

APPENDIX H

DETAILED MUFFLER DESIGNS AND PERFORMANCE ESTIMATES

This appendix contains the detailed muffler designs discussed in Sec. 3. Each muffler is described in terms of its physical dimensions and its estimated attenuation and backpressure performance. The dimensions of each muffler are described in terms of successive "elements", each element being a cross section of the muffler having a given length and specified inlet and outlet areas. The computer-produced tables describe the sections as "approximately circular", although, in fact, they are rectangular; for acoustic purposes, the two are equivalent if the cross-sectional area is the same.

The additional backpressure for each muffler is shown at the bottom of the table of dimensions. Attenuation performance is shown in a second table, which displays the original and modified A-weighted noise levels in each one-third octave band, as well as the overall A-weighted levels with and without the muffler.

The tables relating to the manifold muffler designed for the GP-38 (Tables A-5 through A-8) must be read somewhat differently from the tables for the turbocharged locomotives. In the case of the Roots-blown engines, the existing manifold provides some attenuation already. To estimate the effectiveness of the suggested larger manifold, the backpressures and noise attenuation of both manifolds must be estimated. The noise benefit of the new manifold is then the difference in attenuation between the new and the old manifolds, and similarly for backpressure.

Because the absolute A-weighted noise level for the exhaust without any manifold is not known, the figure of 114.1 dBA was taken as an arbitrary reference. The absolute A-weighted levels shown in Tables A-6 and A-8 are therefore not correct; the differences in these levels between the two manifold designs, however, are reliably estimated.

TABLE A-1

DIMENSIONS AND PREDICTED BACKPRESSURE OF MUFFLER FOR EMD GP-35

```
                         SYSTEM PARAMETERS

   VOLUME VELOCITY =              25500.00  CU. FT./MIN.
   TEMPERATURE =                    850.    DEG. F
   MAX. STATIC PRESS. DROP =      2767.97   IN. OF WATER
   MIN. STATIC PRESS. DROP =     -2767.97   IN. OF WATER
   MAXIMUM MACH NUMBER =              1.000
   EXIT CONDITIONS:                 FREE FIELD
   ENGINE REFLECTION COEFF. =         .000
   SOUND VELOCITY, 32F =          1208.20   FPS

        THE FOLLOWING ELEMENTS ARE USED IN THIS CASE.

ELEMENT NUMBER  1 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                         1.22 IN.
   AREA OF INLET =                210.62 SQ. IN.
   AREA OF OUTLET =               252.77 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.164

ELEMENT NUMBER  2 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                         1.02 IN.
   AREA OF INLET =                252.03 SQ. IN.
   AREA OF OUTLET =               380.02 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.137

ELEMENT NUMBER  3 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                         1.20 IN.
   AREA OF INLET =                380.00 SQ. IN.
   AREA OF OUTLET =               360.22 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.115

ELEMENT NUMBER  4 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                         1.62 IN.
   AREA OF INLET =                360.32 SQ. IN.
   AREA OF OUTLET =               600.03 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.096

ELEMENT NUMBER  5 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                         0.01 IN.
   AREA OF INLET =                600.02 SQ. IN.
   AREA OF OUTLET =              2924.02 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.257

ELEMENT NUMBER  6 IS A RECTANGULAR TUBE.
   LENGTH =       9.30 IN.
   HEIGHT =      43.20 IN.
   WIDTH =       68.00 IN.
ALL THE WALLS ARE RIGID.
MAX. MACH NUMBER IN DUCT =        0.012

ELEMENT NUMBER  7 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                         0.21 IN.
   AREA OF INLET =               2924.22 SQ. IN.
   AREA OF OUTLET =               483.22 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.272
```

TABLE A-1. (Cont.)

```
ELEMENT NUMBER  8 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                           1.22 IN.
   AREA OF INLET =                  482.42 SQ. IN.
   AREA OF OUTLET =                 318.02 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.176

ELEMENT NUMBER  9 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                           2.00 IN.
   AREA OF INLET =                  318.20 SQ. IN.
   AREA OF OUTLET =                 161.60 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.244

ELEMENT NUMBER 10 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                           1.00 IN.
   AREA OF INLET =                  161.33 SQ. IN.
   AREA OF OUTLET =                 132.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.261

ELEMENT NUMBER 11 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                           1.06 IN.
   AREA OF INLET =                  132.22 SQ. IN.
   AREA OF OUTLET =                 144.02 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.261

ELEMENT NUMBER 12 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                           1.22 IN.
   AREA OF INLET =                  144.02 SQ. IN.
   AREA OF OUTLET =                 168.62 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.239

ELEMENT NUMBER 13 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                           3.02 IN.
   AREA OF INLET =                  168.77 SQ. IN.
   AREA OF OUTLET =                 210.20 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.225

ELEMENT NUMBER 14 IS A RECTANGULAR TUBE.
   LENGTH =      6.22 IN.
   HEIGHT =      7.33 IN.
   WIDTH =      32.22 IN.
ALL THE WALLS ARE RIGID.
MAX. MACH NUMBER IN DUCT =         0.168

   CALCULATED STATIC PRESSURE DROP =     4.57 IN. OF WATER
```

TABLE A-2

PREDICTED ATTENUATION PERFORMANCE OF MUFFLER FOR EMD GP-35

F	SPL	MUFF	IL
25.	71.0	73.0	-2.0
32.	70.0	73.9	-3.9
40.	70.0	77.7	-7.7
50.	89.0	103.0	-14.0
63.	79.0	82.9	-3.9
80.	87.5	84.0	3.5
100.	101.0	92.2	8.8
128.	99.5	86.4	13.1
160.	94.0	77.5	16.5
200.	96.0	77.1	18.9
250.	101.5	81.5	20.0
320.	103.0	84.4	18.6
400.	103.0	91.4	11.6
500.	100.0	86.3	13.7
630.	103.0	87.1	15.9
800.	103.0	90.6	12.4
1000.	103.0	87.1	15.9
1250.	103.0	89.4	13.6
1600.	104.0	82.0	22.0
2000.	104.0	84.1	19.9
2500.	104.0	82.2	21.8
3200.	101.0	77.8	23.2
4000.	98.0	74.3	23.7
5000.	94.5	71.8	22.7
6300.	92.0	70.2	21.8
8000.	88.0	65.8	22.2
10000.	82.0	61.2	20.8

MUFF(OVERAL) = 104.6 DBA
SPL (OVERAL) = 114.1 DBA

MUFF : SOUND PRESSURE LEVEL (DBA) WITH MUFFLER
SPL : " " " " WITH NO MUFFLER
IL : MUFFLER INSERTION LOSS (DB)
MUFF(OVERAL) : OVERALL DBA WITH MUFFLER
SPL (OVERAL) : OVERALL DBA WITH NO MUFFLER

ALL SOUND PRESSURE LEVELS MEASURED AT A DISTANCE OF 2.5 FT FROM THE LOCOMOTIVE EXHAUST STACK.

TABLE A-3

DIMENSIONS AND PREDICTED BACKPRESSURE OF MUFFLER FOR EMD GP-40

```
                          SYSTEM PARAMETERS

   VOLUME VELOCITY =             29000.00  CU. FT./MIN.
   TEMPERATURE =                   850.    DEG. F
   MAX. STATIC PRESS. DROP =   2767.97  IN. OF WATER
   MIN. STATIC PRESS. DROP =  -2767.97  IN. OF WATER
   MAXIMUM MACH NUMBER =            1.000
   EXIT CONDITIONS:               FREE FIELD
   ENGINE REFLECTION COEFF. =      .000
   SOUND VELOCITY, 32F =        1088.00  FPS

        THE FOLLOWING ELEMENTS ARE USED IN THIS CASE.

ELEMENT NUMBER  1 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         1.00 IN.
   AREA OF INLET =                210.00 SQ. IN.
   AREA OF OUTLET =               232.50 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.187

ELEMENT NUMBER  2 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         1.00 IN.
   AREA OF INLET =                232.50 SQ. IN.
   AREA OF OUTLET =               260.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.169

ELEMENT NUMBER  3 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         1.00 IN.
   AREA OF INLET =                260.00 SQ. IN.
   AREA OF OUTLET =               305.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.151

ELEMENT NUMBER  4 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         0.01 IN.
   AREA OF INLET =                305.00 SQ. IN.
   AREA OF OUTLET =              2275.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.102

ELEMENT NUMBER  5 IS A RECTANGULAR TUBE.
   LENGTH =      15.00 IN.
   HEIGHT =      35.00 IN.
   WIDTH =       65.00 IN.
ALL THE WALLS ARE RIGID.
MAX. MACH NUMBER IN DUCT =         0.017

ELEMENT NUMBER  6 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         0.01 IN.
   AREA OF INLET =               2275.00 SQ. IN.
   AREA OF OUTLET =               315.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.124
```

TABLE A-3. (Cont.)

```
ELEMENT NUMBER  7 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         0.75 IN.
   AREA OF INLET =                315.00 SQ. IN.
   AREA OF OUTLET =               199.50 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.196

ELEMENT NUMBER  8 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         0.75 IN.
   AREA OF INLET =                199.50 SQ. IN.
   AREA OF OUTLET =               159.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.247

ELEMENT NUMBER  9 IS A RECTANGULAR TUBE.
   LENGTH =      1.00 IN.
   HEIGHT =      6.00 IN.
   WIDTH =      26.50 IN.
ALL THE WALLS ARE RIGID.
MAX. MACH NUMBER IN DUCT =         0.247

ELEMENT NUMBER 10 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         1.50 IN.
   AREA OF INLET =                159.00 SQ. IN.
   AREA OF OUTLET =               189.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.247

ELEMENT NUMBER 11 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                         3.00 IN.
   AREA OF INLET =                189.00 SQ. IN.
   AREA OF OUTLET =               270.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =         0.207

ELEMENT NUMBER 12 IS A RECTANGULAR TUBE.
   LENGTH =      5.50 IN.
   HEIGHT =      9.00 IN.
   WIDTH =      30.00 IN.
ALL THE WALLS ARE RIGID.
MAX. MACH NUMBER IN DUCT =         0.145

   CALCULATED STATIC PRESSURE DROP =     3.16 IN. OF WATER
```

TABLE A-4

PREDICTED ATTENUATION PERFORMANCE OF MUFFLER FOR EMD GP-40

F	SPL	MUFF	IL
25.	71.0	69.4	1.6
32.	70.0	70.3	-0.3
40.	70.0	74.0	-4.0
50.	89.0	99.3	-10.3
63.	79.0	80.2	-1.2
80.	87.5	81.5	6.0
100.	101.0	89.9	11.1
128.	99.5	84.5	15.0
160.	94.0	75.9	18.1
200.	96.0	75.7	20.3
250.	101.5	80.2	21.3
320.	103.0	82.8	20.2
400.	103.0	88.1	14.9
500.	100.0	90.9	9.1
630.	103.0	93.5	9.5
800.	103.0	90.8	12.2
1000.	103.0	88.0	15.0
1250.	103.0	86.1	16.9
1600.	104.0	85.8	18.2
2000.	104.0	84.7	19.3
2500.	104.0	83.1	20.9
3200.	101.0	81.5	19.5
4000.	98.0	78.3	19.7
5000.	94.5	74.9	19.6
6300.	92.0	73.8	18.2
8000.	88.0	70.9	17.1
10000.	82.0	66.6	15.4

MUFF(OVERAL) = 102.5 DBA
SPL (OVERAL) = 114.1 DBA

MUFF : SOUND PRESSURE LEVEL (DBA) WITH MUFFLER
SPL : " " " " WITH NO MUFFLER
IL : MUFFLER INSERTION LOSS (DB)
MUFF(OVERAL) : OVERALL DBA WITH MUFFLER
SPL (OVERAL) : OVERALL DBA WITH NO MUFFLER

ALL SOUND PRESSURE LEVELS MEASURED AT A DISTANCE OF 2.5 FT FROM THE LOCOMOTIVE EXHAUST STACK.

TABLE A-5

DIMENSIONS* AND PREDICTED BACKPRESSURE OF EXISTING MANIFOLD ON EMD GP-38

```
                         SYSTEM PARAMETERS

   VOLUME VELOCITY =              9500.00  CU. FT./MIN.
   TEMPERATURE =                   850.    DEG. F
   MAX. STATIC PRESS. DROP =   2767.97  IN. OF WATER
   MIN. STATIC PRESS. DROP =  -2767.97  IN. OF WATER
   MAXIMUM MACH NUMBER =           1.000
   EXIT CONDITIONS:               FREE FIELD
   ENGINE REFLECTION COEFF. =      .000
   SOUND VELOCITY, 32F =        1088.00  FPS

        THE FOLLOWING ELEMENTS ARE USED IN THIS CASE.

ELEMENT NUMBER  1 IS A RECTANGULAR TUBE.
   LENGTH =      10.00 IN.
   HEIGHT =      10.00 IN.
   WIDTH =       10.00 IN.
ALL THE WALLS ARE RIGID.
MAX. MACH NUMBER IN DUCT =        0.120

ELEMENT NUMBER  2 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                       0.01 IN.
   AREA OF INLET =              100.00 SQ. IN.
   AREA OF OUTLET =             648.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.120

ELEMENT NUMBER  3 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                       9.00 IN.
   AREA OF INLET =              648.00 SQ. IN.
   AREA OF OUTLET =            1296.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.020

ELEMENT NUMBER  4 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                       9.00 IN.
   AREA OF INLET =             1296.00 SQ. IN.
   AREA OF OUTLET =             648.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.020

ELEMENT NUMBER  5 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                       0.01 IN.
   AREA OF INLET =              648.00 SQ. IN.
   AREA OF OUTLET =             105.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =        0.122

ELEMENT NUMBER  6 IS A RECTANGULAR TUBE.
   LENGTH =      36.00 IN.
   HEIGHT =       7.00 IN.
   WIDTH =       15.00 IN.
ALL THE WALLS ARE RIGID.
MAX. MACH NUMBER IN DUCT =        0.122

   CALCULATED STATIC PRESSURE DROP =     5.64 IN. OF WATER
```

---

*Dimensions correspond to an acoustically equivalent analog of the manifold rather than the actual unit.

TABLE A-6

PREDICTED ATTENUATION PERFORMANCE OF EXISTING MANIFOLD ON EMD GP-38

F	SPL	MUFF	IL
25.	71.0	76.4	-5.4
32.	70.0	79.9	-9.9
40.	70.0	74.3	-4.3
50.	89.0	85.9	3.1
63.	79.0	70.5	8.5
80.	87.5	74.8	12.7
100.	101.0	85.0	16.0
128.	99.5	81.3	18.2
160.	94.0	75.4	18.6
200.	96.0	80.9	15.1
250.	101.5	90.3	11.2
320.	103.0	83.0	20.0
400.	103.0	84.8	18.2
500.	100.0	95.4	4.6
630.	103.0	92.5	10.5
800.	103.0	89.3	13.7
1000.	103.0	91.2	11.8
1250.	103.0	86.1	16.9
1600.	104.0	87.7	16.3
2000.	104.0	87.0	17.0
2500.	104.0	85.5	18.5
3200.	101.0	82.5	18.5
4000.	98.0	78.1	19.9
5000.	94.5	74.0	20.5
6300.	92.0	71.8	20.2
8000.	88.0	68.4	19.6
10000.	82.0	63.5	18.5

MUFF(OVERAL) = 100.9 DBA
SPL (OVERAL) = 114.1 DBA

MUFF : SOUND PRESSURE LEVEL (DBA) WITH MUFFLER
SPL : " " " " WITH NO MUFFLER
IL : MUFFLER INSERTION LOSS (DB)
MUFF(OVERAL) : OVERALL DBA WITH MUFFLER
SPL (OVERAL) : OVERALL DBA WITH NO MUFFLER

ALL SOUND PRESSURE LEVELS MEASURED AT A DISTANCE OF 2.5 FT FROM THE LOCOMOTIVE EXHAUST STACK.

TABLE A-7

DIMENSIONS* AND PREDICTED BACKPRESSURE OF SUGGESTED MANIFOLD MUFFLER FOR EMD GP-38

```
                         SYSTEM PARAMETERS

    VOLUME VELOCITY =             9500,00  CU, FT,/MIN,
    TEMPERATURE =                  850,    DEG, F
    MAX, STATIC PRESS, DROP =   2767,97  IN, OF WATER
    MIN, STATIC PRESS, DROP =  -2767,97  IN, OF WATER
    MAXIMUM MACH NUMBER =          1,000
    EXIT CONDITIONS:              FREE FIELD
    ENGINE REFLECTION COEFF, =     ,000
    SOUND VELOCITY, 32F =       1088,00  FPS

         THE FOLLOWING ELEMENTS ARE USED IN THIS CASE,


ELEMENT NUMBER  1 IS A RECTANGULAR TUBE,
   LENGTH =      10,00 IN,
   HEIGHT =      10,00 IN,
   WIDTH =       10,00 IN,
ALL THE WALLS ARE RIGID,
MAX, MACH NUMBER IN DUCT =        0,120


ELEMENT NUMBER  2 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                        0,01 IN,
   AREA OF INLET =               100,00 SQ, IN,
   AREA OF OUTLET =              936,00 SQ, IN,
MAX, MACH NUMBER IN DUCT =        0,120


ELEMENT NUMBER  3 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                        9,00 IN,
   AREA OF INLET =               936,00 SQ, IN,
   AREA OF OUTLET =             2656,00 SQ, IN,
MAX, MACH NUMBER IN DUCT =        0,014


ELEMENT NUMBER  4 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                        9,00 IN,
   AREA OF INLET =              2656,00 SQ, IN,
   AREA OF OUTLET =              936,00 SQ, IN,
MAX, MACH NUMBER IN DUCT =        0,014


ELEMENT NUMBER  5 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                        0,01 IN,
   AREA OF INLET =               936,00 SQ, IN,
   AREA OF OUTLET =              105,00 SQ, IN,
MAX, MACH NUMBER IN DUCT =        0,122


ELEMENT NUMBER  6 IS A RECTANGULAR TUBE,
   LENGTH =      36,00 IN,
   HEIGHT =       7,00 IN,
   WIDTH =       15,00 IN,
ALL THE WALLS ARE RIGID,
MAX, MACH NUMBER IN DUCT =        0,122


   CALCULATED STATIC PRESSURE DROP =     6,00 IN, OF WATER
```

---

*Dimensions correspond to an acoustically equivalent analog of the manifold muffler rather than the unit as installed.

TABLE A-8

PREDICTED ATTENUATION PERFORMANCE OF SUGGESTED MANIFOLD MUFFLER FOR EMD GP-38

F	SPL	MUFF	IL
25.	71.0	77.3	-6.3
32.	70.0	67.3	2.7
40.	70.0	61.3	8.7
50.	89.0	75.5	13.5
63.	79.0	61.4	17.6
80.	87.5	66.4	21.1
100.	101.0	77.2	23.8
120.	99.5	74.0	25.5
160.	94.0	68.7	25.3
200.	96.0	75.0	21.0
250.	101.5	85.3	16.2
320.	103.0	80.7	22.3
400.	103.0	87.2	15.8
500.	100.0	87.3	12.7
630.	103.0	85.1	17.9
800.	103.0	84.8	18.2
1000.	103.0	85.2	17.8
1250.	103.0	86.5	16.5
1600.	104.0	85.4	18.6
2000.	104.0	83.5	20.5
2500.	104.0	82.7	21.3
3200.	101.0	79.3	21.7
4000.	98.0	75.0	23.0
5000.	94.5	71.5	23.0
6300.	92.0	68.9	23.1
8000.	88.0	65.2	22.8
10000.	82.0	60.5	21.5

OVERAL = 96.1 DBA

MUFF(OVERAL) = 96.1 DBA
SPL (OVERAL) = 114.1 DBA

MUFF : SOUND PRESSURE LEVEL (DBA) WITH MUFFLER
SPL : " " " " WITH NO MUFFLER
IL : MUFFLER INSERTION LOSS (DB)
MUFF(OVERAL) : OVERALL DBA WITH MUFFLER
SPL (OVERAL) : OVERALL DBA WITH NO MUFFLER

ALL SOUND PRESSURE LEVELS MEASURED AT A DISTANCE OF 2.5 FT FROM THE LOCOMOTIVE EXHAUST STACK.

TABLE A-9

DIMENSIONS AND PREDICTED BACKPRESSURE OF MUFFLER FOR GE U25, U33, and U36

```
                    SYSTEM PARAMETERS

   VOLUME VELOCITY =             25000.00  CU. FT./MIN.
   TEMPERATURE =                   850.    DEG. F
   MAX. STATIC PRESS. DROP =      2767.97  IN. OF WATER
   MIN. STATIC PRESS. DROP =     -2767.97  IN. OF WATER
   MAXIMUM MACH NUMBER =            1.000
   EXIT CONDITIONS:                FREE FIELD
   ENGINE REFLECTION COEFF. =       .000
   SOUND VELOCITY, 32F =         1088.00  FPS

        THE FOLLOWING ELEMENTS ARE USED IN THIS CASE.

ELEMENT NUMBER  1 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                          8.00 IN.
   AREA OF INLET =                 165.00 SQ. IN.
   AREA OF OUTLET =                210.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =          0.205

ELEMENT NUMBER  2 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                          4.00 IN.
   AREA OF INLET =                 210.00 SQ. IN.
   AREA OF OUTLET =                300.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =          0.161

ELEMENT NUMBER  3 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                          0.01 IN.
   AREA OF INLET =                 300.00 SQ. IN.
   AREA OF OUTLET =                576.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =          0.113

ELEMENT NUMBER  4 IS A RECTANGULAR TUBE.
   LENGTH =     40.00 IN.
   HEIGHT =     16.00 IN.
   WIDTH =      36.00 IN.
ALL THE WALLS ARE RIGID.
MAX. MACH NUMBER IN DUCT =          0.059

ELEMENT NUMBER  5 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                          0.01 IN.
   AREA OF INLET =                 576.00 SQ. IN.
   AREA OF OUTLET =                300.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =          0.113

ELEMENT NUMBER  6 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION.
   LENGTH =                          0.01 IN.
   AREA OF INLET =                 300.00 SQ. IN.
   AREA OF OUTLET =                576.00 SQ. IN.
MAX. MACH NUMBER IN DUCT =          0.113
```

TABLE A-9. (Cont.)

```
ELEMENT NUMBER  7 IS A RECTANGULAR TUBE,
   LENGTH =      80,00 IN,
   HEIGHT =      16,00 IN,
   WIDTH =       36,00 IN,
ALL THE WALLS ARE RIGID,
MAX, MACH NUMBER IN DUCT =       0,059

ELEMENT NUMBER  8 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                        0,01 IN,
   AREA OF INLET =               576,00 SQ, IN,
   AREA OF OUTLET =              300,00 SQ, IN,
MAX, MACH NUMBER IN DUCT =       0,113

ELEMENT NUMBER  9 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                        4,00 IN,
   AREA OF INLET =               300,00 SQ, IN,
   AREA OF OUTLET =              250,00 SQ, IN,
MAX, MACH NUMBER IN DUCT =       0,135

ELEMENT NUMBER 10 IS AN APPROXIMATELY CIRCULAR, RIGID TRANSITION,
   LENGTH =                        4,00 IN,
   AREA OF INLET =               250,00 SQ, IN,
   AREA OF OUTLET =              200,00 SQ, IN,
MAX, MACH NUMBER IN DUCT =       0,169

ELEMENT NUMBER 11 IS A RECTANGULAR TUBE,
   LENGTH =      20,00 IN,
   HEIGHT =      11,00 IN,
   WIDTH =       17,00 IN,
ALL THE WALLS ARE RIGID,
MAX, MACH NUMBER IN DUCT =       0,168

   CALCULATED STATIC PRESSURE DROP =     1,41 IN, OF WATER
```

TABLE A-10

PREDICTED ATTENUATION PERFORMANCE OF MUFFLER FOR GE U25, U33, and U36

F	SPL	MUFF	IL
25.	71.0	82.3	-11.3
32.	70.0	71.1	-1.1
40.	70.0	65.5	4.5
50.	89.0	81.6	7.4
63.	79.0	71.7	7.3
80.	87.5	84.3	3.2
100.	101.0	91.7	9.3
128.	99.5	87.3	12.2
160.	94.0	87.4	6.6
200.	96.0	84.5	11.5
250.	101.5	100.5	1.0
320.	103.0	98.2	4.0
400.	103.0	91.2	11.8
500.	100.0	90.2	9.8
630.	103.0	89.7	13.3
800.	103.0	87.7	15.3
1000.	103.0	83.9	19.1
1250.	103.0	81.3	21.7
1600.	104.0	80.6	23.4
2000.	104.0	79.0	25.0
2500.	104.0	77.3	26.7
3200.	101.0	73.1	27.9
4000.	98.0	70.2	27.8
5000.	94.5	66.7	27.8
6300.	92.0	65.7	26.3
8000.	88.0	65.4	22.6
10000.	82.0	62.5	19.5

MUFF(OVERAL) = 104.1 DBA
SPL (OVERAL) = 114.1 DBA

MUFF : SOUND PRESSURE LEVEL (DBA) WITH MUFFLER
SPL : " " " " WITH NO MUFFLER
IL : MUFFLER INSERTION LOSS (DB)
MUFF(OVERAL) : OVERALL DBA WITH MUFFLER
SPL (OVERAL) : OVERALL DBA WITH NO MUFFLER

ALL SOUND PRESSURE LEVELS MEASURED AT A DISTANCE OF 2.5 FT FROM THE LOCOMOTIVE EXHAUST STACK.

Appendix I

SPACE AVAILABILITY FOR MUFFLERS INSIDE LOCOMOTIVES

NOISE LEVELS AND SPACE AVAILABILITY

In this section, we summarize additional locomotive noise level data acquired during the course of this program and discuss space availability for the installation of mufflers on a range of locomotives. This information is based, in large part, on a number of field studies that are discussed in detail in Appendices B, C, and D.

Additional Noise Levels

Table 4-1 provides idle and throttle 8 data on noise from 12 locomotives. Several measurements were taken at sites that were usually nonideal because of the unavoidable presence of reflecting surfaces such as cars, other locomotives, and buildings. However, the data are still of value in that they represent upper bounds to clear-site locomotive levels.

Space Availability

The principal factors to consider when determining the space available for locomotive mufflers are: (1) clearance space around and within the locomotive, (2) backpressure generated if exhaust is ducted to remote locations, and (3) visibility.

External clearance profiles have been established by the AAR for various levels of service interchangeability of locomotives and cars among various railroads and routes (Railway Equipment and Publication Co. 1973). The tightest clearance profile which allows for unrestricted interchange service is shown in figure 4-1. The dimension of greatest interest is the overall height of 15 ft 1 in. because of the above-hood location appropriate to many locomotives. A less stringent standard height of 15 ft 6 in. is suitable for use on 95 percent of total mileage in eastern railroads.

TABLE 4-1.

SUMMARY OF STATIONARY LOCOMOTIVE NOISE LEVELS

Locomotive Mfr/Model	Load Device	Noise Level at 100 Ft			Source
		Ambient	Idle	Throttle 8	
GM/GP-9	Load Cell	-	67[1] dBA	89 dBA[1]	Appendix B
GM/GP-38-2	Self Load	-	66.5 dBA[1]	92 dBA[1]	Appendix C
GM/GP-9	Load Cell	-	69 dBA[1]	89 dBA[1]	Appendix C
MLW/M-420[2]	Load Cell	-	65 dBA[1]	87 dBA[1]	Appendix D
GE/U36C Road No. 3322 Rated 3600 hp	Self Load	57 dBA	68 dBA	87 dBA	State of New Jersey
GE/U36C Road No. 3322 Rated 3600 hp, Actual 3564 hp	Load Cell	55 dBA	68 dBA	90 dBA	State of New Jersey
GE/U34CH Road No. 3358 Rated 3435 hp, Actual 3497 hp	Load Cell	57 dBA	70 dBA[3]	87 dBA	State of New Jersey
GM/SD45-2 Road No. 3680 Rated 3600 hp, Actual 3840 hp	Load Cell	60 dBA	66 dBA	91 dBA	State of New Jersey
GE/U25B Road No. 2502 Rated 2500 hp, Actual 2375 hp	Load Cell	64 dBA	70 dBA	92 dBA	State of New Jersey
Alco/C424 Road No. 2406 Rated 2400 hp, Actual 1760-2297 hp (surging)	Load Cell	65 dBA	72 dBA	89 dBA[4]	State of New Jersey
GE/U33C Road No. 3314 Rated 3300 hp, Actual 3278 hp	Load Cell	60 dBA	69 dBA	90 dBA	State of New Jersey
GM/GP-9 Road No. 1262 Rated 1750 hp, Actual 1878 hp	Load Cell	61 dBA	68 dBA	92 dBA	State of New Jersey
GM/GP-35 Road No. 2556 Rated 2500 hp, Actual 2424 hp	Load Cell	59 dBA	69 dBA	86 dBA	State of New Jersey

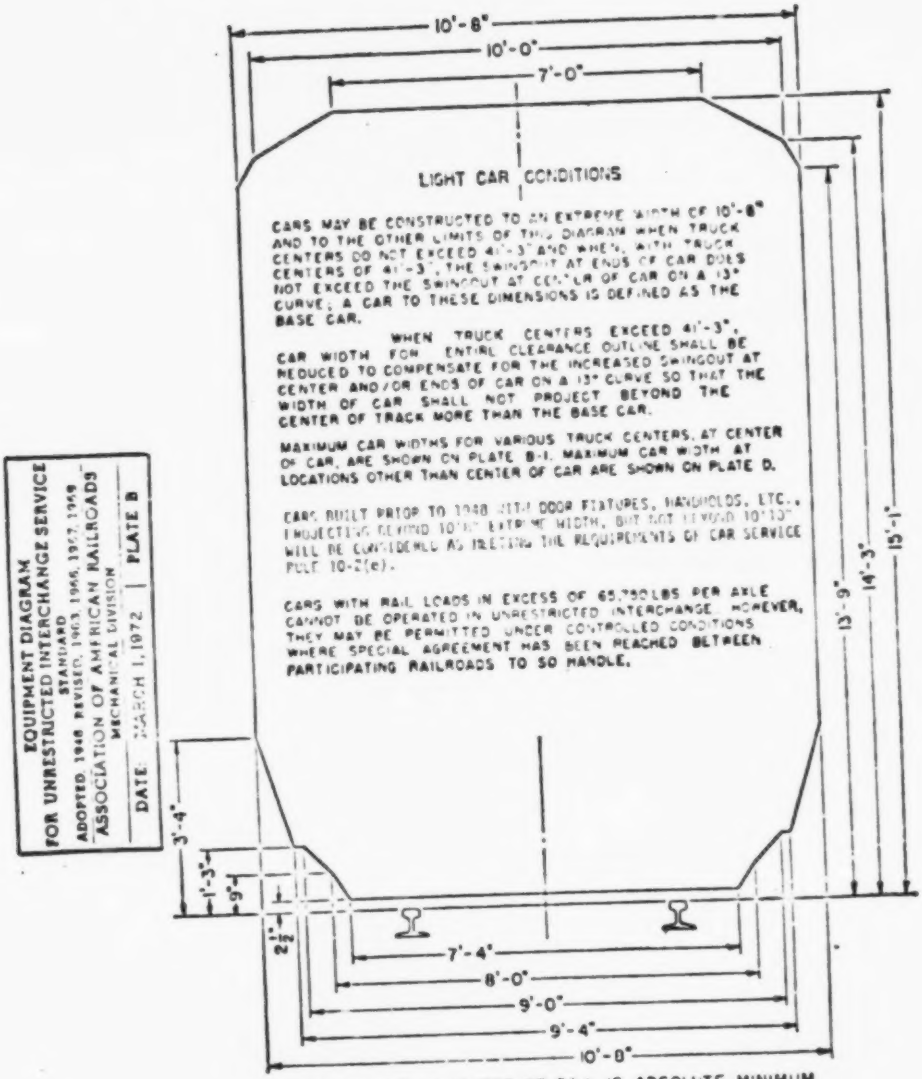
---

[1] Nonideal test site, usually because of sound-reflecting objects within 100 ft of locomotive or microphone.

[2] The Montreal Locomotive Works M-420 model is very similar to the Alco C-420 series.

[3] At 450 rpm. This locomotive can have three idling conditions depending on the electrical requirements (heating, lights, etc.) of the passenger cars.

[4] This test considered not representative since the engine was not developing full power.



LIGHT CAR CONDITIONS

CARS MAY BE CONSTRUCTED TO AN EXTREME WIDTH OF 10'-8" AND TO THE OTHER LIMITS OF THIS DIAGRAM WHEN TRUCK CENTERS DO NOT EXCEED 41'-3" AND WHEN, WITH TRUCK CENTERS OF 41'-3", THE SWINGOUT AT ENDS OF CAR DOES NOT EXCEED THE SWINGOUT AT CENTER OF CAR ON A 13° CURVE; A CAR TO THESE DIMENSIONS IS DEFINED AS THE BASE CAR.

WHEN TRUCK CENTERS EXCEED 41'-3", CAR WIDTH FOR ENTIRE CLEARANCE OUTLINE SHALL BE REDUCED TO COMPENSATE FOR THE INCREASED SWINGOUT AT CENTER AND/OR ENDS OF CAR ON A 13° CURVE SO THAT THE WIDTH OF CAR SHALL NOT PROJECT BEYOND THE CENTER OF TRACK MORE THAN THE BASE CAR.

MAXIMUM CAR WIDTHS FOR VARIOUS TRUCK CENTERS, AT CENTER OF CAR, ARE SHOWN ON PLATE B-1. MAXIMUM CAR WIDTH AT LOCATIONS OTHER THAN CENTER OF CAR ARE SHOWN ON PLATE D.

CARS BUILT PRIOR TO 1948 WITH DOOR FIXTURES, HANDHOLDS, ETC., PROJECTING BEYOND 10'-8" EXTREME WIDTH, BUT NOT BEYOND 10'-10" WILL BE CONSIDERED AS MEETING THE REQUIREMENTS OF CAR SERVICE RULE 10-2(e).

CARS WITH RAIL LOADS IN EXCESS OF 65,750 LBS PER AXLE CANNOT BE OPERATED IN UNRESTRICTED INTERCHANGE. HOWEVER, THEY MAY BE PERMITTED UNDER CONTROLLED CONDITIONS WHERE SPECIAL AGREEMENT HAS BEEN REACHED BETWEEN PARTICIPATING RAILROADS TO SO HANDLE.

EQUIPMENT DIAGRAM
FOR UNRESTRICTED INTERCHANGE SERVICE
STANDARD
ADOPTED 1948 REVISED 1963, 1966, 1967, 1969
ASSOCIATION OF AMERICAN RAILROADS
MECHANICAL DIVISION
DATE: MARCH 1, 1972 | PLATE B

THE 2-1/2" ABOVE TOP OF RAIL IS ABSOLUTE MINIMUM UNDER ANY AND ALL CONDITIONS OF LADING, OPERATION, AND MAINTENANCE.

ALL NEW OR REBUILT CARS SHOULD BE SO DESIGNED THAT NO PART OF CAR SHALL BE LESS THAN 2-3/4" ABOVE THE TOP OF THE RUNNING RAIL UNDER ALL ALLOWABLE WEAR AND SPRING DEFLECTION CONDITIONS. THOSE ROADS USING MULTIPLE WEAR WHEELS MAY FIND IT NECESSARY, IN MAINTAINING THE 2-3/4" MINIMUM CLEARANCE, TO COMPENSATE FOR WHEELS WORN CLOSE TO THE CONDEMNING LIMIT BY REPLACING WHEEL AND AXLE SETS, BEARINGS OR WEDGES,.

FIGURE 4-1. RAILROAD CLEARANCE DIAGRAM. SOURCE: Railway Time Clearances (1973).

Reproduced from best available copy.

Western railroads often use higher equipment. For example, the Burlington Northern operates GP-38 and GP-40 locomotives that are 6 ft from top-of-rail (Burlington Northern Railroad Co.). Since the 15-ft 6-in. clearance height applies so widely, it is the one we shall use in evaluating the above-hood space.

Backpressure requirements are usually sufficiently stringent to preclude remote location of mufflers at the ends, or possibly the sides, of locomotives. Backpressure accrues from flow through the ducting from the top of the engine to remote locations. Accordingly, we consider applying mufflers only above the engine, either above or below the locomotive hood.

It is generally stated that switchers need their low hoods for visibility and that mufflers would interfere with this visibility. Yet visibility does not seem to be an essential factor, as is shown by the frequent use of high-hooded GP-7 and GP-9 locomotives as switchers. Also, the volume of the muffler can be distributed over the length and breadth of the hood, so that the vertical dimension need not be large. For example, a muffler having the same volume as the Maxim MSA-1 for a 12-cylinder EMD 645E engine (42.4 ft^3) could be built to have dimensions of 5 ft in width, 10 ft in length, and less than a foot in height. Such a muffler would easily fit over the hood of an EMD SW1500 switcher with minimum visibility interference.

One of the very real problems of evaluating space availability is the large number of locomotive types. Before considering many of these types in detail, let us consider some of the general geometries of road- and switcher-type units.

The most common road locomotive is the high-hood type, with a cab that protrudes on each side for purposes of fore-and-aft visibility. An example of this type of locomotive is the General Motors GP-9, shown in figure 4-2 (Pinkepank, 1973). These locomotives have only limited space above the hood for the installation of mufflers.

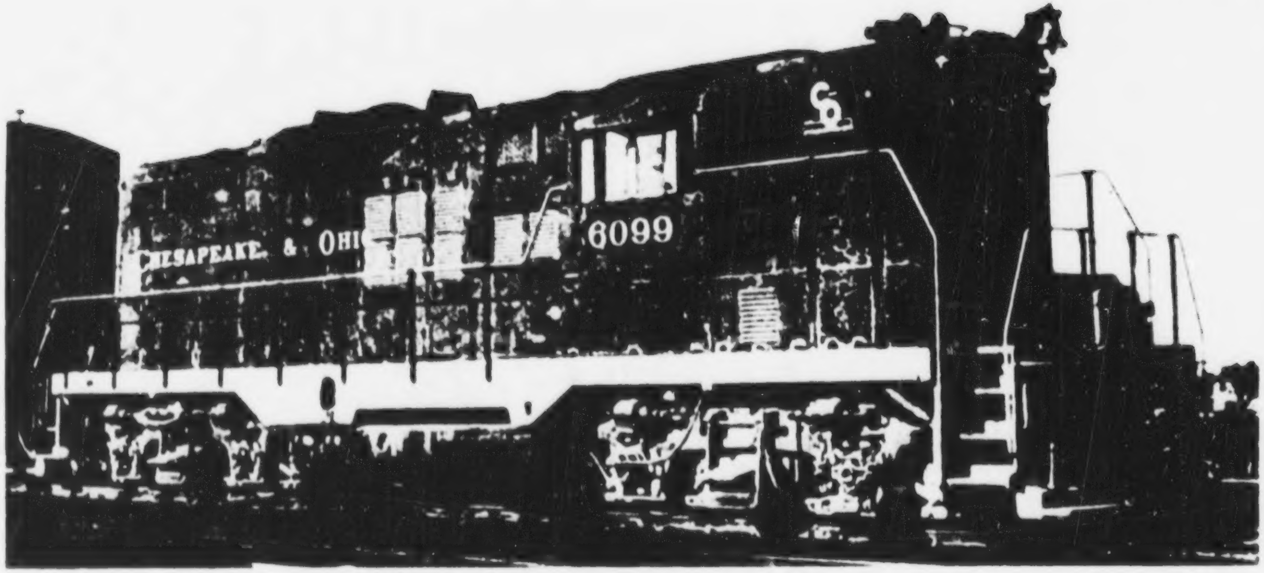


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FIGURE 4-2. GENERAL MOTORS GP-9 LOCOMOTIVE.

A second type of road locomotive structure is represented by the General Motors F9A locomotive illustrated in figure 4-3. Although this locomotive is more streamlined than the GP type, it does not have rearward visibility and cannot easily be run backwards. Accordingly, it has not been popular and has been out of production for about 15 years, although about 1500 of these locomotives are still in service. The F-type locomotives also have limited above-load space for muffler applications.

Switcher locomotives are quite another matter. The General Motors Sw.1000 switcher, illustrated in figure 4-4, shows that there is nearly 3 ft of vertical space above the hood (Burlington Northern Railroad Co.). There is also a substantial amount of space rearward and laterally.

A detailed evaluation of space availability is given in Table 4-2. This table applies to locomotives in service at the beginning of 1974; the population data were obtained from Osthoff (1974). Note that switchers* have from 2½ to 4 ft of height above the hood, which is adequate for the installation of mufflers. Certain road locomotives such as the GP-9 have as much as 2 ft of space above the hood for which a muffler could be designed. Also, some of these locomotives have below-hood space for an expanded exhaust manifold that would reduce noise emissions.

The preceding discussion of available space is based largely on inspection of the interior plans of a large number of locomotive models and, in some cases, on visual inspections of the locomotives themselves. In all cases, judgments of space available were based on the locomotive configuration as delivered by the manufacturer. It is possible that some locomotive users have modified the internal arrangements of their units in ways that

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*GM designation NW and SW; Alco designation S and RS.

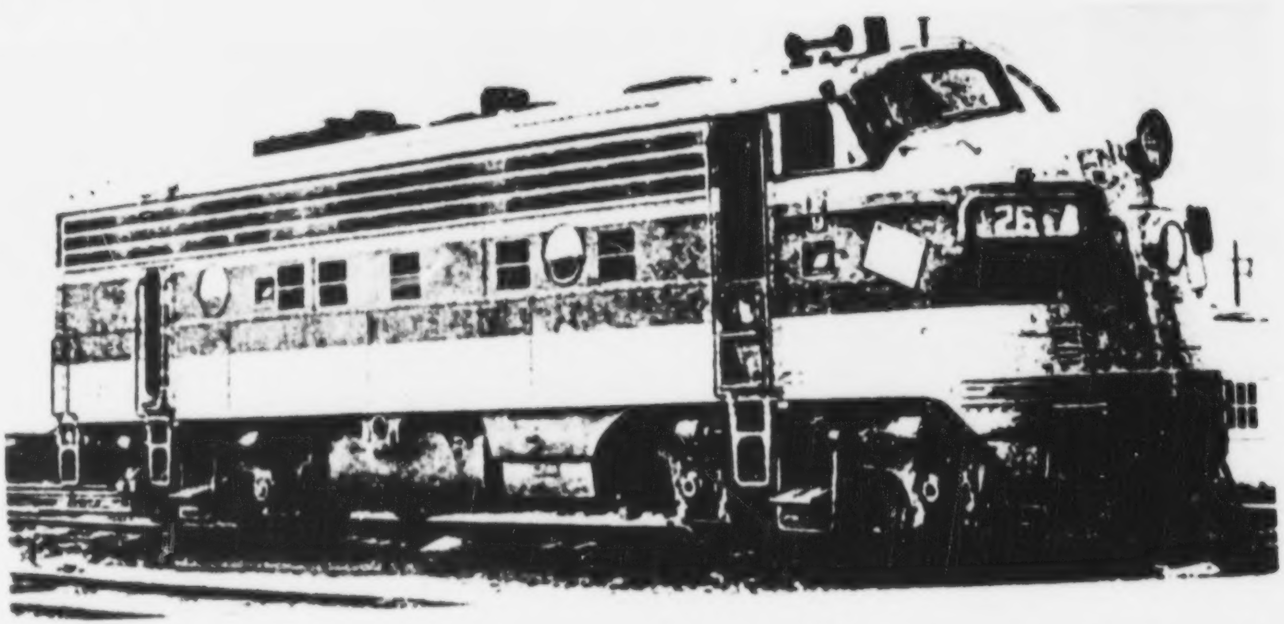

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FIGURE 4-3. GENERAL MOTORS F9A LOCOMOTIVE.

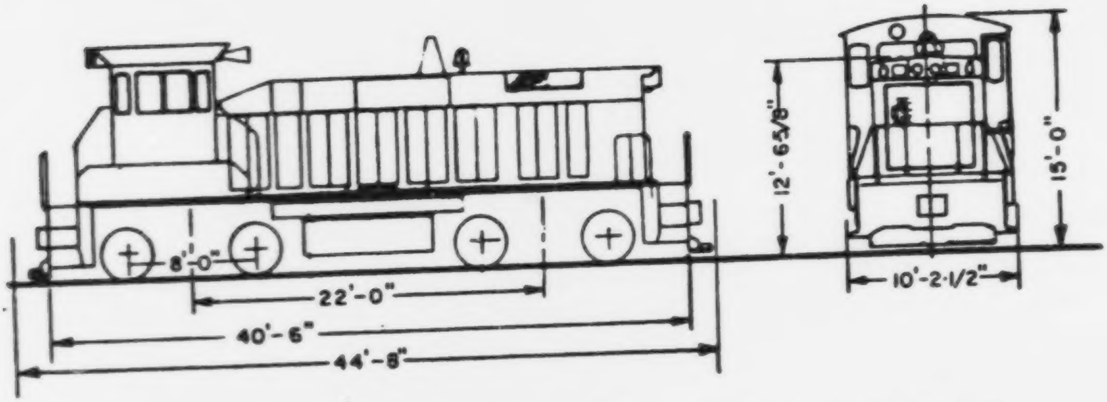

FIGURE 4.4. EMD SW. 1000 — 1000 hp LOCOMOTIVE.

would hamper muffler installation, such as by rerouting cables or piping. Such components would have to be moved to permit muffler installation. The number of locomotives in which this may be a problem is unknown; it could only be determined by a detailed unit-by-unit survey.

TABLE 4.2

LOCOMOTIVE SPACE AVAILABILITY AND POPULATION

Model	Space for Muffler Length/Width/Height (Dimensions in Inches)		No. in Service[1] as of 1/1/74
	Under Hood	Above Hood	
EMD NW2		-/72/42[2](±6)	684
NW3			
NW5		-/72/42[2](±6)	
SW1		-/72/46[2](±6)	
SW8		-/72/42[2](±6)	
SW600		-/72/42[2](±6)	
SW900		-/72/40[2](±6)	
SW7		-/72/42[2](±6)	2626
SW9		-/72/42[2](±6)	
SW1000		-/72/35[2](±1/2)	
SW1200			
W1500		-/72/36[2](±6)	685
F3		-/84/18[2](±6)	3645
F7		-/84/17[2](±1/2)	
GP7	Enlarge exhaust manifold to 27 in. diam.	-/84/19[2](±1/2)	
SD7	Enlarge exhaust manifold to 27 in. diam.	-84/19[2](±1/2)	
F9		-/84/17[2](±1/2)	3884
GP9	Enlarge exhaust manifold to 27 in. diam.	-/84/24[2](±1/2)	
SD9	Enlarge exhaust manifold to 27 in. diam.	-/84/18[2](±6)	
GP18		-/84/24[2](±6)	400
GP28			
GP38	Enlarge exhaust manifold to 27 in. diam.	Insufficient[3]	1886
SD38	Enlarge exhaust manifold to 27 in. diam.	Insufficient[3]	
GP20		-/84/18[2](±6)	200
SD24		-/84/ -[2]	295

TABLE 4.2

LOCOMOTIVE SPACE AVAILABILITY AND POPULATION *(Cont.)*

EMD GP30 SD30	37/72/36[5]	Insufficient[3]	1196
GP35 SD35	36/72/32[5]	Insufficient[3]	1583
GP39		Insufficient[3]	92
GP40 SD40	48/72/32[5] 48/72/32[5]	-/84/18[2](±1/2) Insufficient	2702
F45 SD45	48/72/36[5]	Insufficient[3] Insufficient[3]	1652
GE U25	163/35/16[4]		552
U28	163/35/16[4]		201
U23	130/35/16[4]		287
U30	163/35/16[4]		677
U33	163/35/16[4]		522
U36	180/35/16[4]		63
U18	97/35/16[4]		65
U50	163/35/16[4]		60
Alco S1,S3, S6,S2,S4 RS1,RSD1 T6		-/-/48	80 579
RS2,RSC-2 FA1,FB1		-/-/30	114
RS3,RSD5 FA/B-2		-/-/30	
RS11,12	144/42/24[6]		362
C420 DL109 PA1	144/42/24[6]		156

TABLE 4.2

LOCOMOTIVE SPACE AVAILABILITY AND POPULATION *(Cont.)*

RSD15 C424	144/42/24[6]	107
C425	144/42/24[6]	84
C628	192/42/18[6]	131
C630 C430	192/42/18[6] 144/42/18[6]	81

---

[1] Source: Osthoff (1974).

[2] Estimated from diagrams in Burlington Northern (undated). Numbers in parentheses designate estimation tolerance.

[3] "Insufficient" is used when space above hood appears to be 12 in. or less.

[4] Strictly speaking, this much space is not available under the hood. The center section of the hood would have to be raised to accommodate a muffler.

[5] Estimated from diagrams in Burlington Northern (undated) and General Motors Corp. (1974). Extended range dynamic brakes are discussed where appropriate.

[6] Obtained from drawings supplied to BBN by Montreal Locomotive Works, Montreal, Canada.

Appendix J

LOCOMOTIVE NOISE MEASUREMENTS TAKEN IN CONJUNCTION WITH HARCO MANUFACTURING COMPANY AND ADDITIONAL MEASUREMENTS

APPENDIX J

MEETING WITH HARCO AND LOCOMOTIVE NOISE MEASUREMENTS

On Tuesday, 21 January 1975, several EPA personnel* and Dr. Erich Bender of BBN met with Mr. Frank N. Harris, Manager of Harco Manufacturing Co., to discuss Harco's activities in locomotive silencing. We also measured the noise of several Union Pacific locomotives under various conditions. In this appendix, we (1) discuss the noise measurements of a GP-9 locomotive in three exhaust-silencing configurations, (2) present noise data on a GP-38-2 locomotive, and (3) identify some salient aspects of Harco's productive capacity.

Noise Measurements — GP-9

During the afternoon of 21 January 1975, noise measurements were made on a Union Pacific GP-9 locomotive (#246) in the Union Pacific yard on Swan Island, Portland.

Test Site. Figure C-1 is a sketch of the test site. The locomotive was connected electrically to a General Electric load cell, and the microphone was located 100 ft from the track centerline between two parallel rows of truck trailers, spaced about 82 ft apart. The large end wall of a locomotive shop was located approximately 50 ft from the locomotive, as indicated. The day was clear, the temperature about 50° F, and the wind very light. Because of the shop wall and trailers, this site is not suitable for certification-type tests but is appropriate for comparative tests of mufflers.

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*Dr. Alvin Meyer, Mr. Henry Thomas, Dr. William Roper, Mr. Jeffrey Cerar.

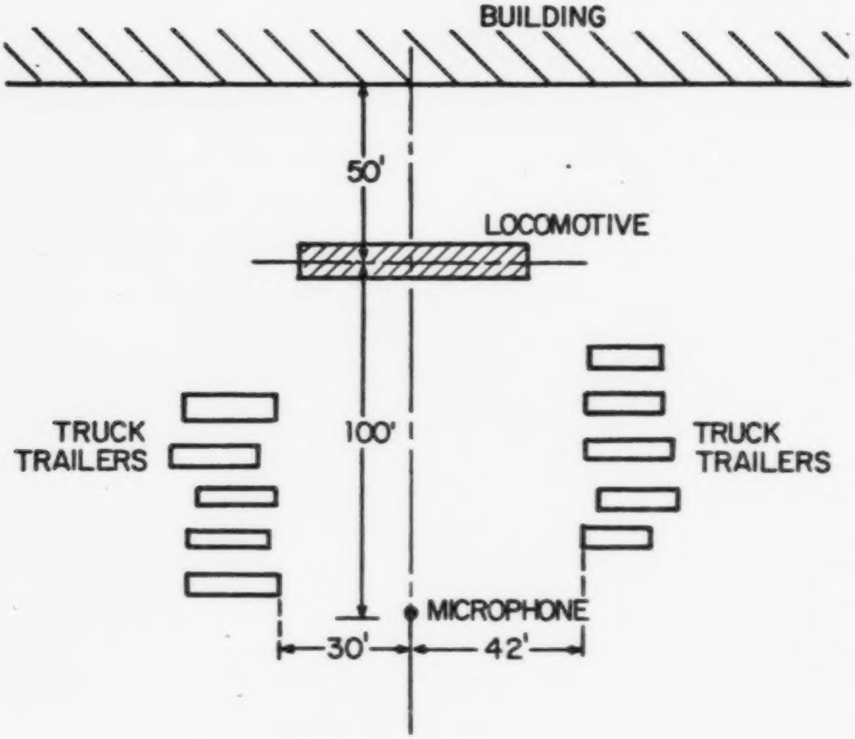


FIGURE C-1. TEST SITE.

Instrumentation. For all measurements on this locomotive, A- and C-scale levels were read directly from a P&K Model 2203 Sound Level Meter equipped with a B&K Model 4145 1-in. microphone and recorded (linear scale) for subsequent analysis of a Kudelski Model Nagra III tape recorder. Before and after the sequence of measurements, the system was calibrated with a B&K 4220 pistonphone.

Mufflers. The performance of two different muffler types was investigated. The first mufflers, called "snubbers," are sketched in figure C-2. They are designed to fit between the car body and the engine. The exhaust gas flows through a perforated sheet metal liner into a cylinder and back through the perforated metal before exiting. The second, called "cross-mounted

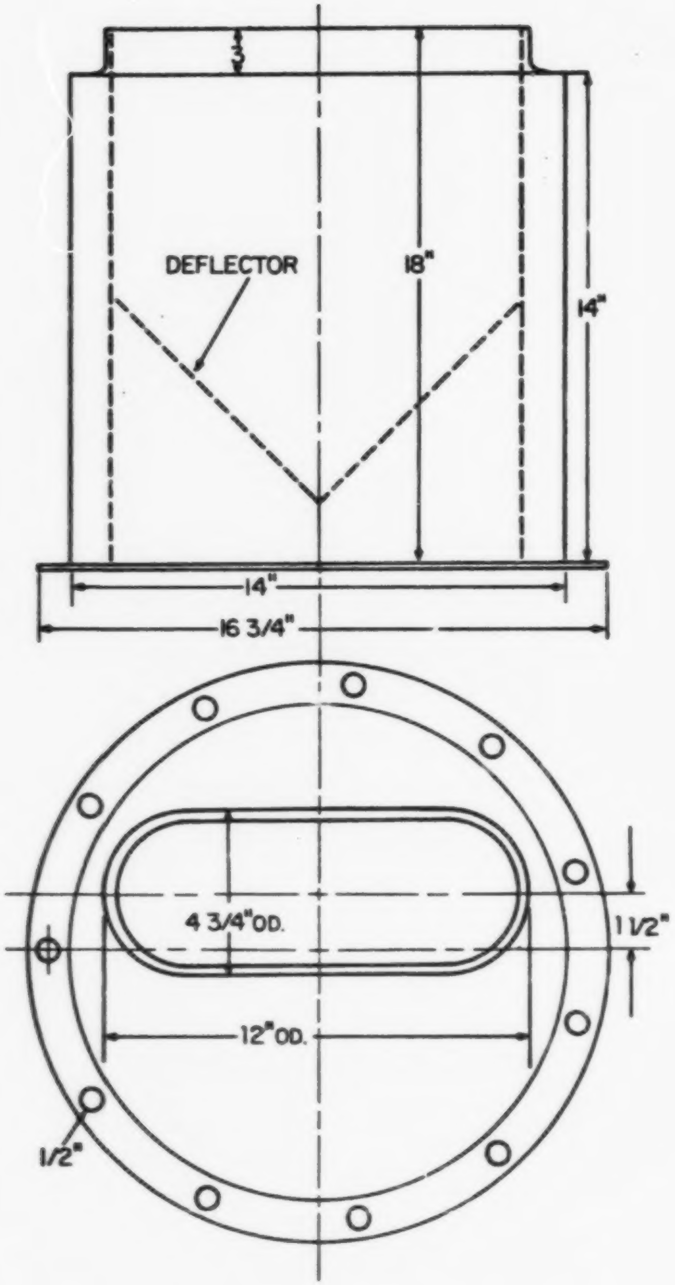
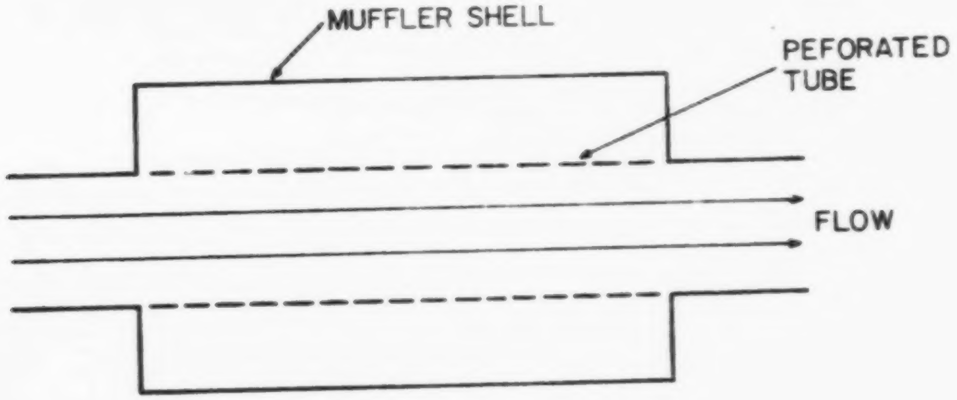

3
DEFLECTOR
18"
14"
14"
16 3/4"
4 3/4" OD.
1 1/2"
12" OD.
1/2"

FIGURE C-2. SNUBBER-TYPE MUFFLER.

mufflers," are designed to fit above the car body but within the clearance envelope. Figure C-3 is a sketch of the outside of the cross-mounted mufflers. Their operation is similar to that of snubbers in that all of the flow is forced through a perforated inner lining.

It should be recognized that the snubber type of muffler in which exhaust gases are forced through perforated material is generally not used in other engine silencing applications. The reason is that substantial backpressures are generated. Muffling is done more efficiently by allowing the bulk of the exhaust gas to flow through a perforated tube, which attenuates sound because only little flow passes through the perforations (see sketch below).



Cost Estimates. Although costs have not been estimated by a detailed manufacturing analysis, Mr. Harris offered the following estimates:

- snubbers: less than $500 for a set of 2 required for a single locomotive

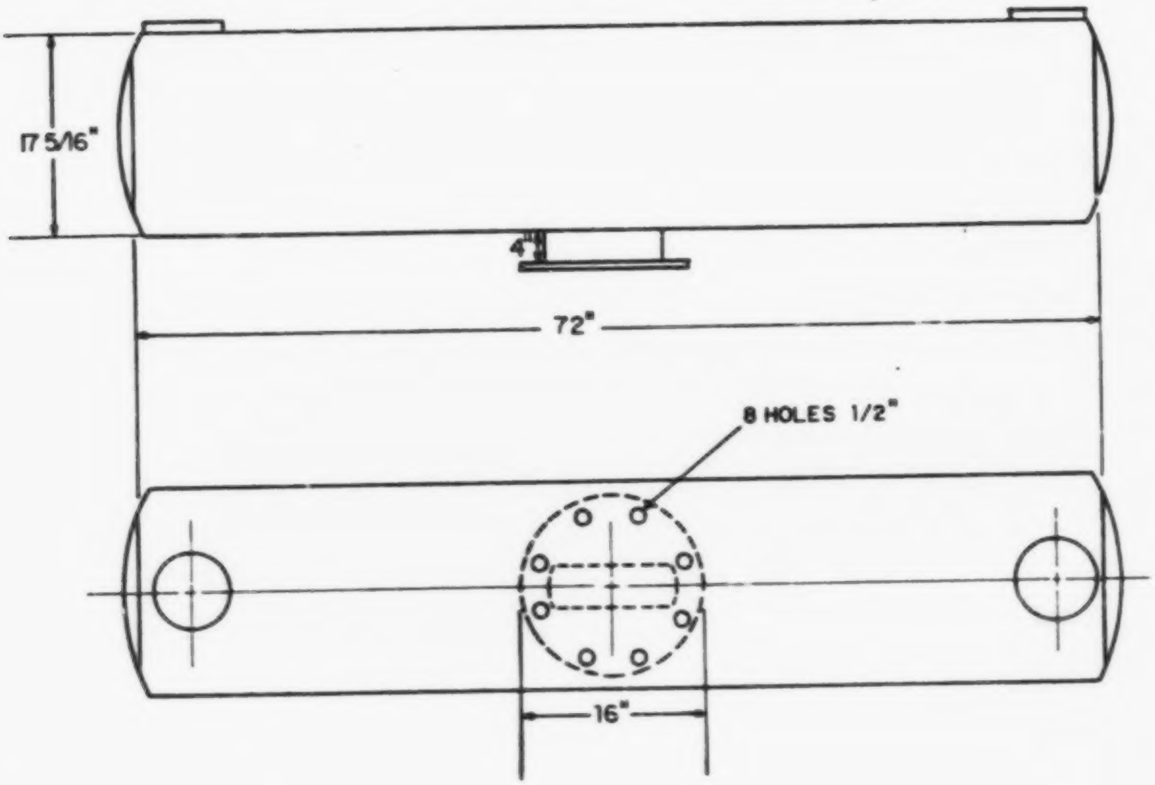

17 5/16"
4"
72"
8 HOLES 1/2"
16"

FIGURE C-3. CROSS-MOUNTED MUFFLER.

- cross-mounted: about $750 per locomotive, or about $1000 per locomotive when integrated with spark arresters.

Life Factors. Since Harco's locomotive mufflers are still developmental, data are not presently available on their durability. However, several observations were made on spark arresters, which attach to a locomotive stack in much the same way as a muffler. First, the primary source of failure appears to be fatigue of flat sections, which resonate. The cure is to raise the resonant frequency by means of stiffeners or by curving each sheet metal element. Corrosion occurs on the outside and only if painting is not performed with sufficient frequency. The interior tends to be protected by an oily coating generated by the engine. Harco personnel expect their spark arresters to last a minimum of 5 years.

Noise Data. Noise levels for the locomotive equipped with mufflers were measured at all throttle settings; only throttle 1 and 8 settings were tested with the unmuffled locomotive.

A and C scale levels for all noise measurements are shown in figure C-4. The following observations may be made:

1. The snubbers provide virtually no noise reduction compared with the unmuffled locomotive. In fact, the A-weighted level at throttle 8 is actually higher without the snubbers than with them. The reason may be that one set of doors on the locomotive was inadvertently left open while the snubbers were being measured. These doors were closed during tests with cross-mounted mufflers and with no mufflers.

2. The A-weighted level increases more rapidly than the C-weighted level with increasing throttle setting. The reason is that as the engine operates at increasingly higher speeds, the noise and vibration shift to higher frequencies where less attenuation is provided by the A-weighting network.

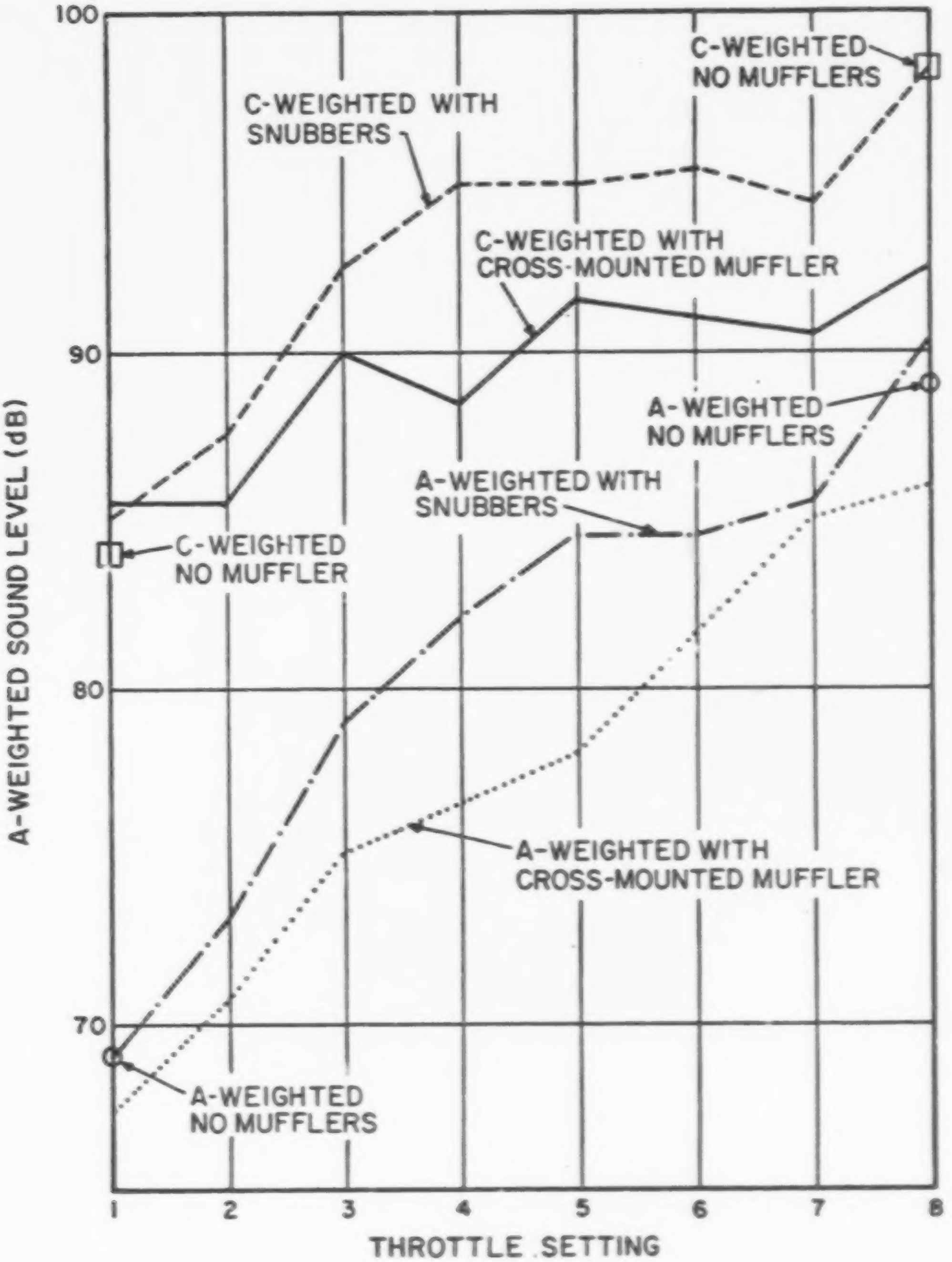
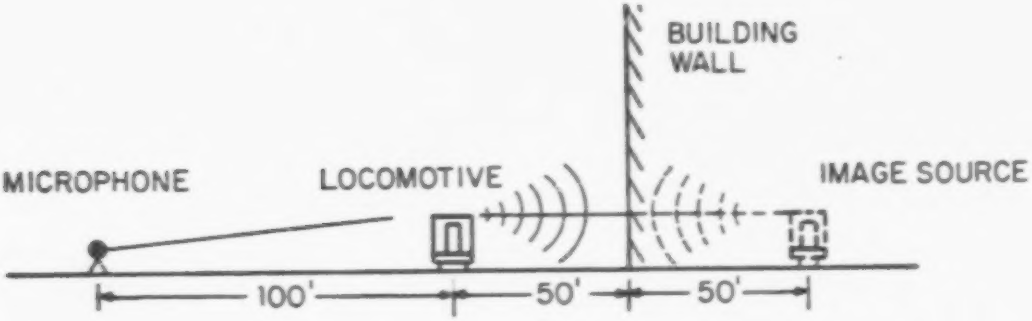


FIGURE C-4. PERFORMANCE OF HARCO MUFFLERS AS A FUNCTION OF THROTTLE SETTING.

3. The cross-mounted mufflers enable the locomotive to meet the proposed 87-dBA throttle 8 standard, but exceed by 0.3 dBA the 67-dBA throttle 1 standard.

Extraneous Factors. Two extraneous factors may have caused the measured noise level to be higher than the level that would have been measured under ideal conditions. They are (1) the pressure of a reflecting shop wall and (2) reflections from two rows of parked truck trailers. Estimates of the effect of each follow.

Reflecting Shop Wall: The level of the sound reflected from the shop wall may be estimated with the assistance of the following sketch.



The sound reflected from the wall may be thought of in terms of an "image source," identical to the actual locomotive but located 50 ft behind the wall location, with the wall removed. This sound propagates over the top of the locomotive and is diffracted down toward the microphone. Attenuation of the reflected sound comprises two parts: spreading and diffraction. Because the reflected sound travels 200 ft (compared with 100 ft in the direct path) to the microphone, the spreading accounts for a 20 log (200/100) = 6-dB reduction in level.

Computing the shielding provided by the locomotive is more detailed. First, we compute the number N given by

$$N = \frac{2}{\lambda} (A + B - d) \quad ,$$

where A is the distance from the top of the locomotive to the microphone ($\sqrt{100^2 + 11^2} \cong 100.65$); B is the distance from the top of the locomotive to the top of its image (100 ft), d is the straight-line distance from the top of the image to the microphone ($\sqrt{200^2 + 11^2} \cong 200.3025$), and λ is the wavelength of sound at frequencies of interest.

Using the above parameter values and noting that $\lambda = 1100/f$, we find

$$N = 0.55 \times 10^{-3} f \quad . \tag{C-1}$$

By using Eq. C-1 and Figure 7-8 of Beranek (1971), we derive the attenuation curve labeled "locomotive shielding" in figure C-5. Note that shielding is more effective at high frequencies than at low frequencies.

To obtain the actual sound spectrum produced at the microphone by the image source, we proceed in two steps.

1. Apply the locomotive shielding curve to the A-weighted octave-band locomotive spectrum shown in figure C-5,* compute the spectrum of reflected sound, add the octave-band levels of each spectrum to obtain the overall A-weighted levels, then take the difference between the two levels to find the overall attenuation from shielding. The result is approximately 10 dBA.

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*This spectrum is an average of the spectra corresponding to the three silencing configurations listed previously, with the locomotive operating in throttle setting 8.

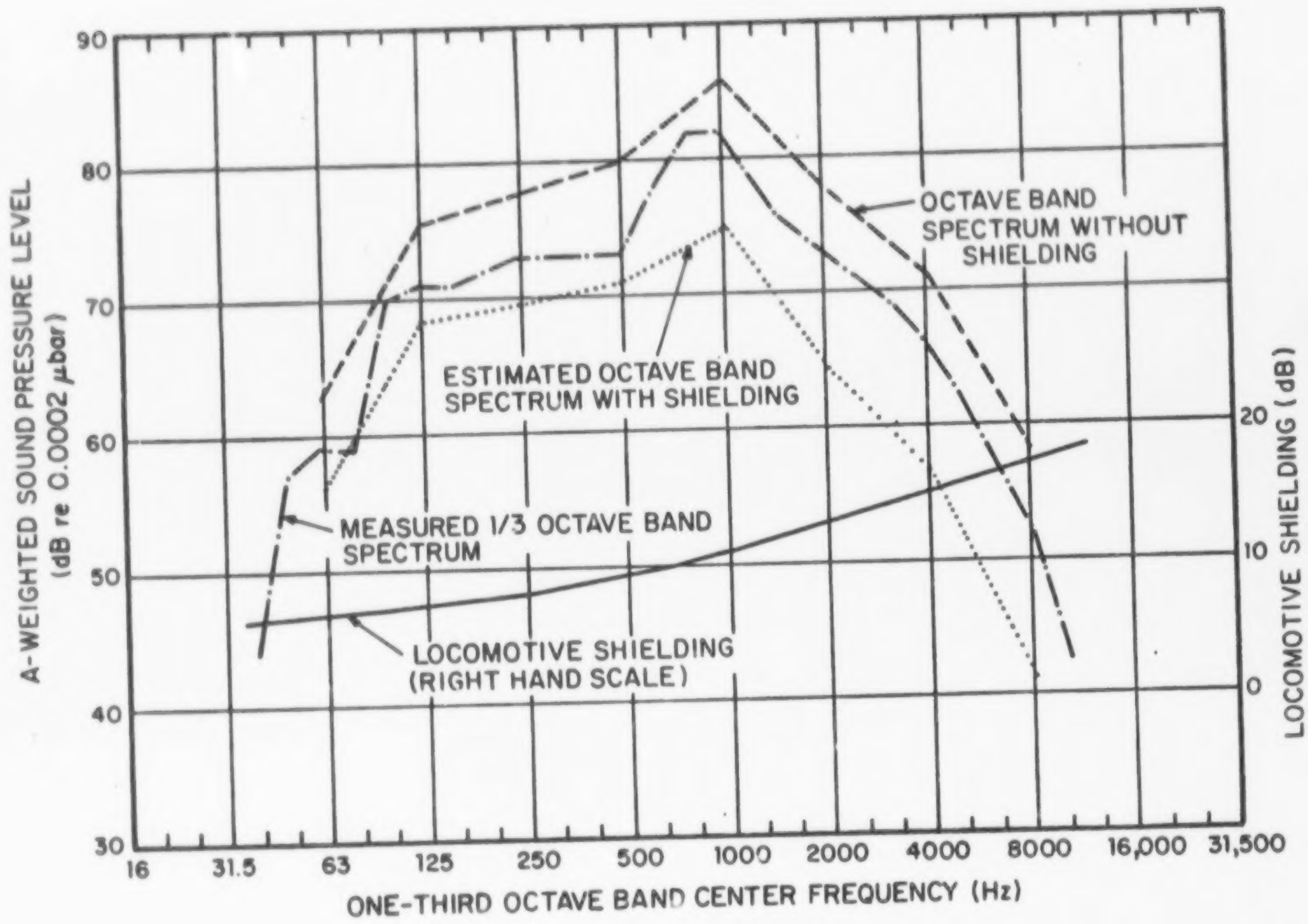
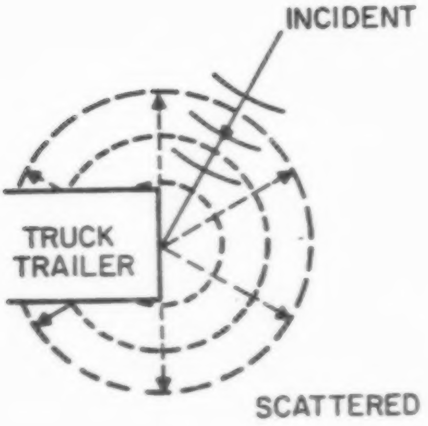


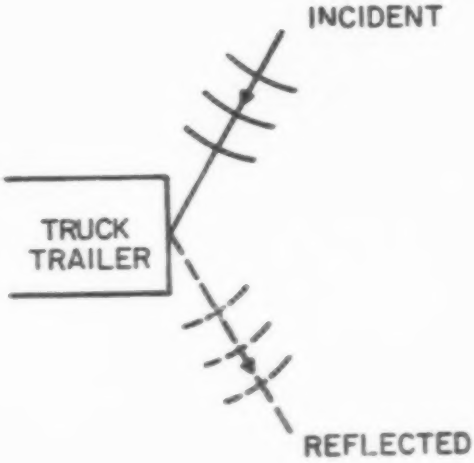
FIGURE C-5. COMPUTATION OF THE EFFECT OF LOCOMOTIVE SHIELDING ON REFLECTED SOUND LEVELS (EXPLANATION IN TEXT).

2. Add the 6-dBA spreading loss to the 10-dBA shielding loss. The result is that the sound reflected from the shop wall, as measured at the microphone, is 16 dBA less than the sound propagating directly to the microphone. This wall reflection thus adds approximately 0.1 dBA to the direct level. Or, if the wall were not present, the level at the microphone would be 0.1 dBA less than measured. The presence of the wall therefore produces a negligible contribution to the measured noise level.

Parallel Rows of Truck Trailers: Sound from the locomotive is reflected or scattered from each of the trailers in parallel rows running perpendicular to the track. This scattered sound adds to the sound propagating directly from the locomotive to the microphone, causing a higher level to be read than if the trucks were absent.

At very low frequencies the sound is scattered nearly uniformly in all directions. (See following sketch.) However, at high frequencies the sound is reflected specularly, much like





light from a mirror. The transition frequency f_t occurs approximately at $f_t = c/\pi\ell = 1100/\pi \cdot 8 \cong 45$ Hz. Since most of the A-weighted acoustic energy is in frequency bands at least a decade above f_t, it is reasonable to consider a specular reflection model.

The problem now is to estimate the spreading attenuation from the increased distance of sound travel and the portion of the locomotive "seen" from the microphone, imagining the trailer ends to be mirrors. The expression for this attenuation A is given by

$$A = 10 \log \frac{100^2 + (2d)^2}{100^2} + 10 \log \frac{a_{total}}{a_{visible}} \quad ,$$

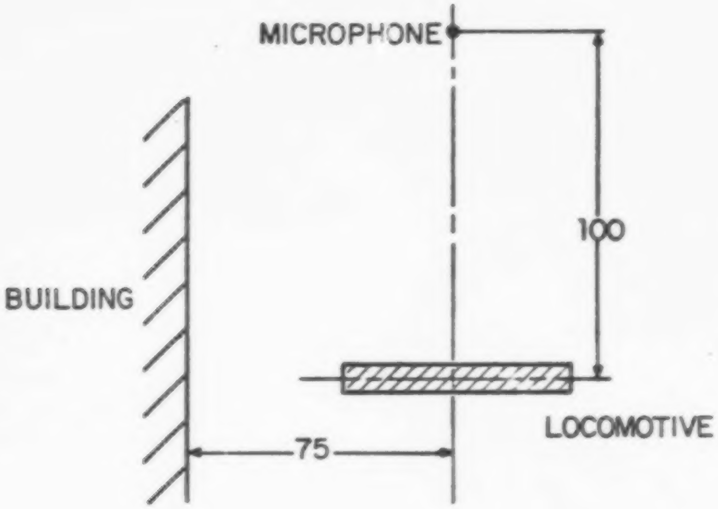
where d is the perpendicular distance from the line connecting the microphone and locomotive center to the trailer ends and a refers to the locomotive area. Since the bottoms of the trailers are approximately 4 ft off the ground, are 8 ft wide, and are separated by approximately 5 ft, and the locomotive is 15 ft high:

$$\frac{a_{total}}{a_{visible}} = \frac{15}{15-4} \cdot \frac{8+5}{8} = 2.2 \quad .$$

For the left row of trailers, d = 30 ft and A = 4.8 dB. For the right row of trailers, d = 42 ft and A = 5.8 dB. Together, the scattered sound level is only about 2.2 dBA lower than the direct level. Thus the measured level can be approximately 2 dBA higher than the level that would exist in the absence of the trailers.

Noise Measurements — GP-38-2

Noise levels of a GP-38-2 locomotive were measured under self-load conditions outside a large shop, as indicated in the following sketch.



Because of reflections from the sides of the shop, the measured noise level is expected to be higher than that which would be measured in free-field conditions. Attenuation A of the reflected wave is estimated from

$$A = 10 \log \frac{100^2 + (2d)^2}{100^2} \quad ,$$

where d = 75 ft and A ≅ 5.1 dB. Therefore, the measured level is about 1.2 dB higher than the free-field level. The measured and corresponding estimated values of free-field levels are shown in Table C-1.

TABLE C-1

VALUES OF FREE-FIELD LEVELS

	Measured Level dBA	Estimated Free Field Level — dBA
Idle	66.5	65.3
Throttle 8	92	90.8

Harco's Productive Capacity

The Harco Manufacturing Co. is a rather small organization with approximately 15 to 25 personnel and about $1 million in sales. However, Mr. Harris claims to have the capacity to deliver up to 6000 muffler units/year (enough for 3000 locomotives) by entering into a licensing or subcontracting arrangement with the Portland Wire and Door Co. This muffler production would be sufficient to equip more than 20 percent of the present locomotive fleet in a 2-year period.

TABLE 4-1.

SUMMARY OF STATIONARY LOCOMOTIVE NOISE LEVELS

Locomotive Mfr/Model	Load Device	Noise Level at 100 ft			Source
		Ambient	Idle	Throttle 8	
GM/GP-9	Load Cell	-	67[1] dBA	89 dBA[1]	Appendix B
GM/GP-38-2	Self Load	-	66.5 dBA[1]	92 dBA[1]	Appendix C
GM/GP-9	Load Cell	-	69 dBA[1]	89 dBA[1]	Appendix C
MLW/M-420[2]	Load Cell	-	65 dBA[1]	87 dBA[1]	Appendix D
GE/U36C Road No. 3322 Rated 3600 hp	Self Load	57 dBA	68 dBA	87 dBA	State of New Jersey
GE/U36C Road No. 3322 Rated 3600 hp, Actual 3564 hp	Load Cell	55 dBA	68 dBA	90 dBA	State of New Jersey
GE/U34CH Road No. 3358 Rated 3435 hp, Actual 3497 hp	Load Cell	57 dBA	70 dBA[3]	87 dBA	State of New Jersey
GM/SD45-2 Road No. 3680 Rated 3600 hp, Actual 3840 hp	Load Cell	60 dBA	66 dBA	91 dBA	State of New Jersey
GE/U25B Road No. 2502 Rated 2500 hp, Actual 2375 hp	Load Cell	64 dBA	70 dBA	92 dBA	State of New Jersey
Alco/C424 Road No. 2406 Rated 2400 hp, Actual 1760-2297 hp (surging)	Load Cell	65 dBA	72 dBA	89 dBA[4]	State of New Jersey
GE/U33C Road No. 3314 Rated 3300 hp, Actual 3278 hp	Load Cell	60 dBA	69 dBA	90 dBA	State of New Jersey
GM/GP-9 Road No. 1262 Rated 1750 hp, Actual 1878 hp	Load Cell	61 dBA	68 dBA	92 dBA	State of New Jersey
GM/GP-35 Road No. 2556 Rated 2500 hp, Actual 2424 hp	Load Cell	59 dBA	69 dBA	86 dBA	State of New Jersey

---

[1] Nonideal test site, usually because of sound-reflecting objects within 100 ft of locomotive or microphone.

[2] The Montreal Locomotive Works M-420 model is very similar to the Alco C-420 series.

[3] At 450 rpm. This locomotive can have three idling conditions depending on the electrical requirements (heating, lights, etc.) of the passenger cars.

[4] This test considered not representative since the engine was not developing full power.

APPENDIX K

EXHAUST NOISE MEASUREMENTS FOR THE GP-9 LOCOMOTIVE

The exhaust noise signature of a GP-9 locomotive was measured during a visit to the B&M service plant at North Billerica, Mass. on November 26, 1974.

Sound pressure levels were obtained 2.5 ft away from one (of two) exhaust stack outlets and 100 ft away from the side of the locomotive.

The data acquisition equipment consisted of the following:

- B&K-4220 pistonphone, Serial No. 221359
- microphone wind screen
- GR-4134 1/2 in. microphone, Serial No. 103016
- GR-1560 P42 preamplifier Serial No. 492
- BBN power supply for the P42
- GR-1551B sound level meter, Serial No. 289
- Nagra IIIB Kudelski Tape Recorder, Serial No. 621789.

Figure B-1 is a rough sketch of the structures in the vicinity of the locomotive. It was not possible to move the locomotive away from all reflecting surfaces to achieve ideal hemispherical space conditions. However, most of these surfaces were far anough away so that any resulting discrepancies are expected to be minimal. There were about 4 in. of snow on the ground surrounding the locomotive.

A sketch of the microphone positions for the 2.5-ft measurements is shown in figure B-2. The overall levels in both the linear and A-scale were monitored in all three positions indicated in figure B-2, and no significant differences were observed.

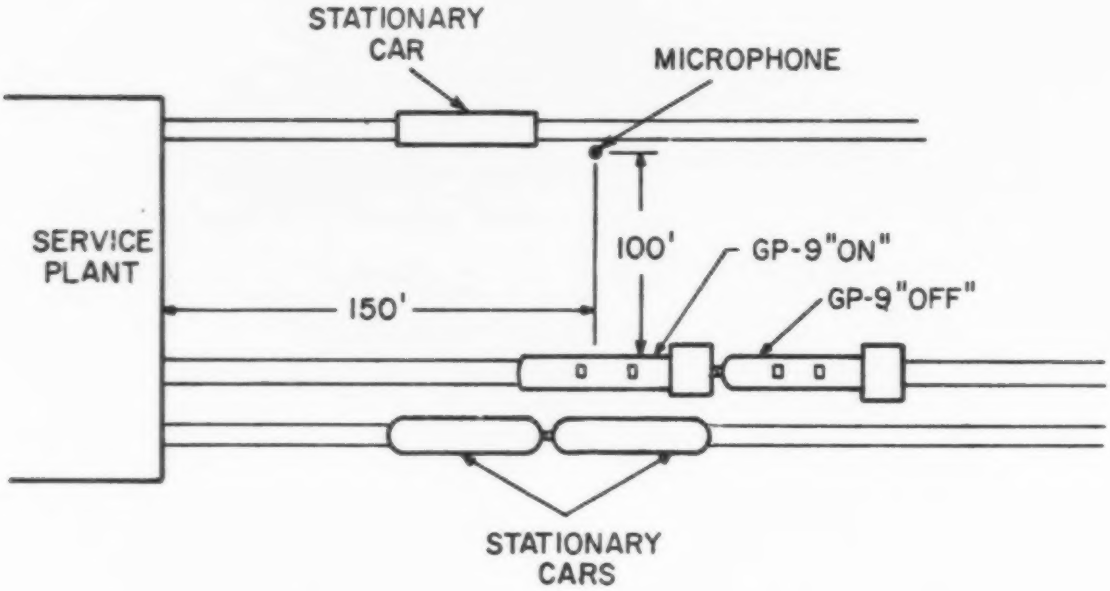

STATIONARY CAR
MICROPHONE
SERVICE PLANT
100'
GP-9"ON"
GP-9"OFF"
150'
STATIONARY CARS

FIGURE B-1. LOCATION OF GP-9 LOCOMOTIVE DURING FARFIELD (100 FT) MEASUREMENTS OF EXHAUST NOISE.

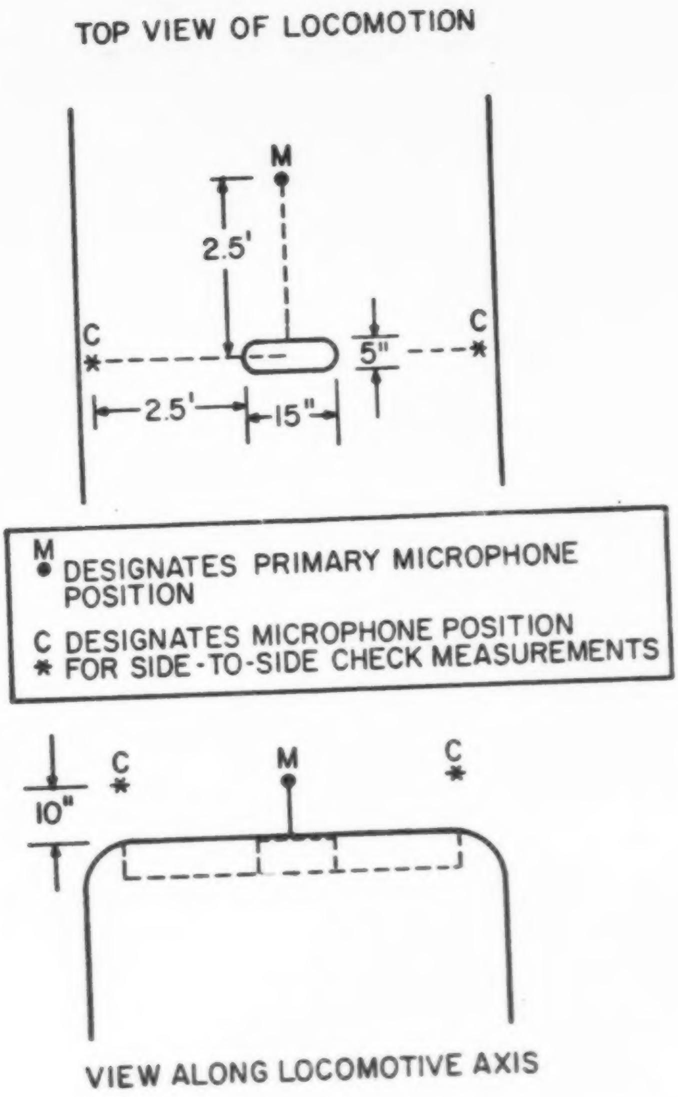

TOP VIEW OF LOCOMOTION
M
2.5'
C
C
5"
2.5'
15"
M DESIGNATES PRIMARY MICROPHONE POSITION
C * DESIGNATES MICROPHONE POSITION FOR SIDE-TO-SIDE CHECK MEASUREMENTS
10"
C
M
C
VIEW ALONG LOCOMOTIVE AXIS

FIGURE B-2. MICROPHONE POSITION FOR NEARFIELD MEASUREMENT OF EXHAUST NOISE.

Figures B-3 through B-5 contain the 1/3-octave band spectra at idle, throttle 8 with no load, and throttle 8 with full load, respectively, corresponding to the 100-ft position. Figures B-6 through B-8 contain the same information for the 2.5-ft position recorded at position B (figure B-2).

The relatively short distance of 2.5 ft from the stack outlet ensures that the recorded sound pressure level L_s (2.5 ft) corresponds solely to exhaust noise. To estimate L_s (100 ft), that is, the contribution of the exhaust to the noise level at 100 ft, we assume spherical spreading and then use

$$\Delta L = L_s\ (2.5\ \mathrm{ft}) - L_s\ (100\ \mathrm{ft}) = 20 \log \left|\frac{100\ \mathrm{ft}}{2.5\ \mathrm{ft}}\right| = 32\ \mathrm{dB}\ .$$

Strictly speaking, the value of ΔL should be decreased by 3 dB because the far field will also contain the contribution of the second stack. At the same time, ΔL should be increased by a similar amount because of partial shadowing; therefore, the two effects cancel each other partially, and the assumed ΔL = 32 dB is expected to offer a good estimate of L_s (100 ft).

The estimated spectrum L_s (100 ft) is compared to the actually measured noise spectrum in figure B-9. Both traces correspond to a throttle 8 with full load setting and follow each other fairly well, a positive indication that the farfield noise is primarily due to exhaust. The trend is also quite similar at throttle 8 with no load and at idle.

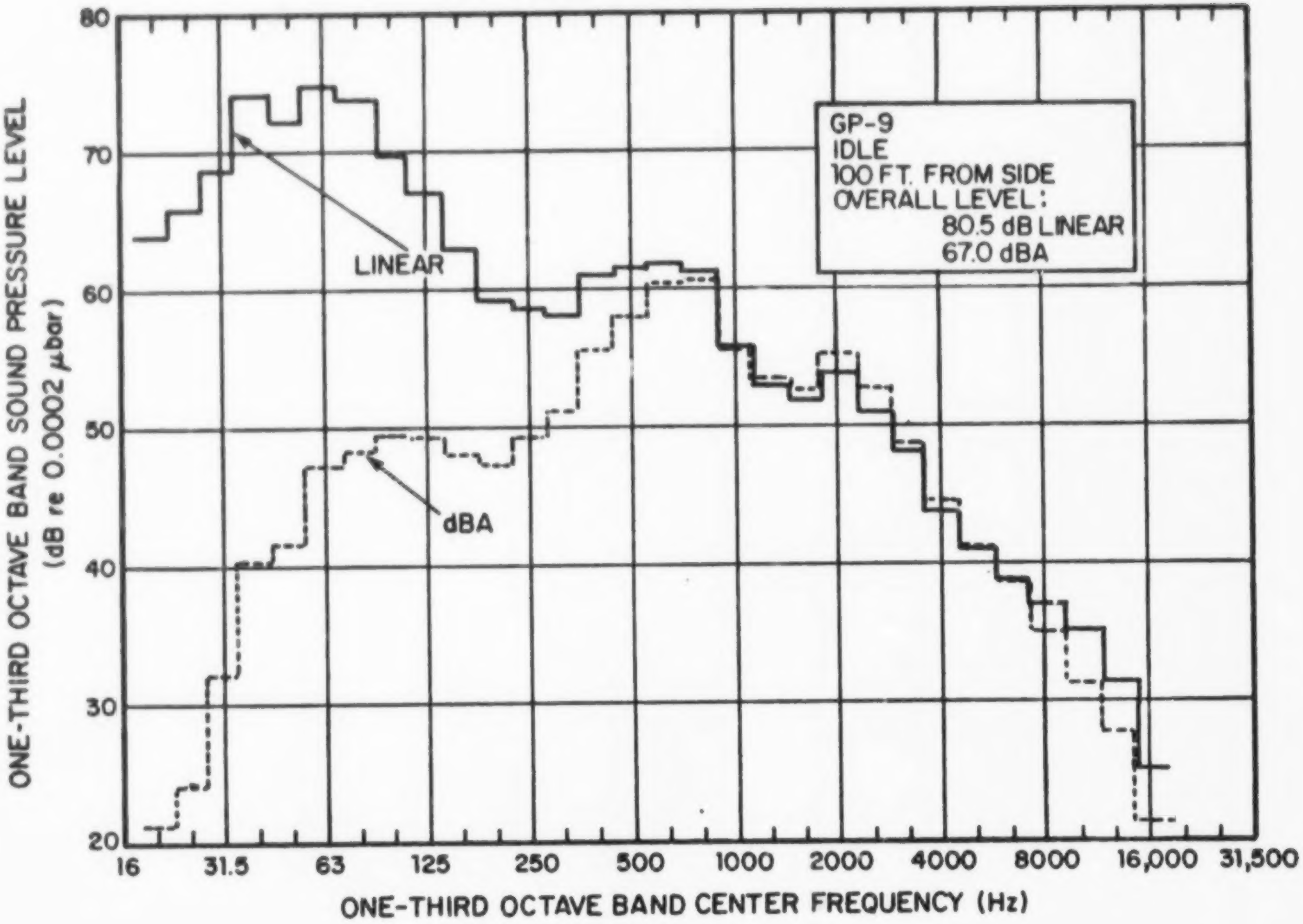


FIGURE B-3. GP-9, IDLE, AT 100 FT.

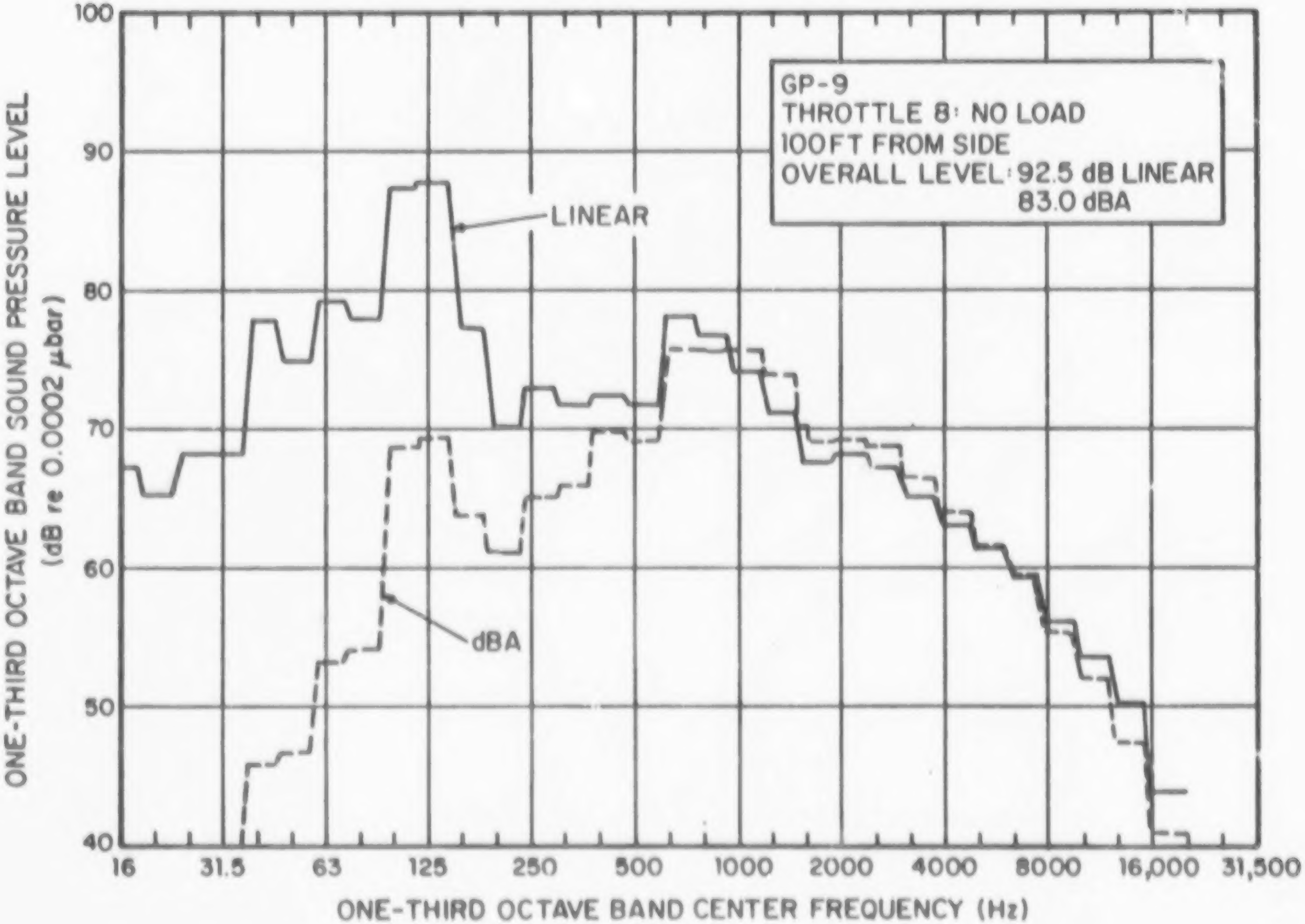


FIGURE B-4. GP-9, THROTTLE 8, NO LOAD, AT 100 FT.

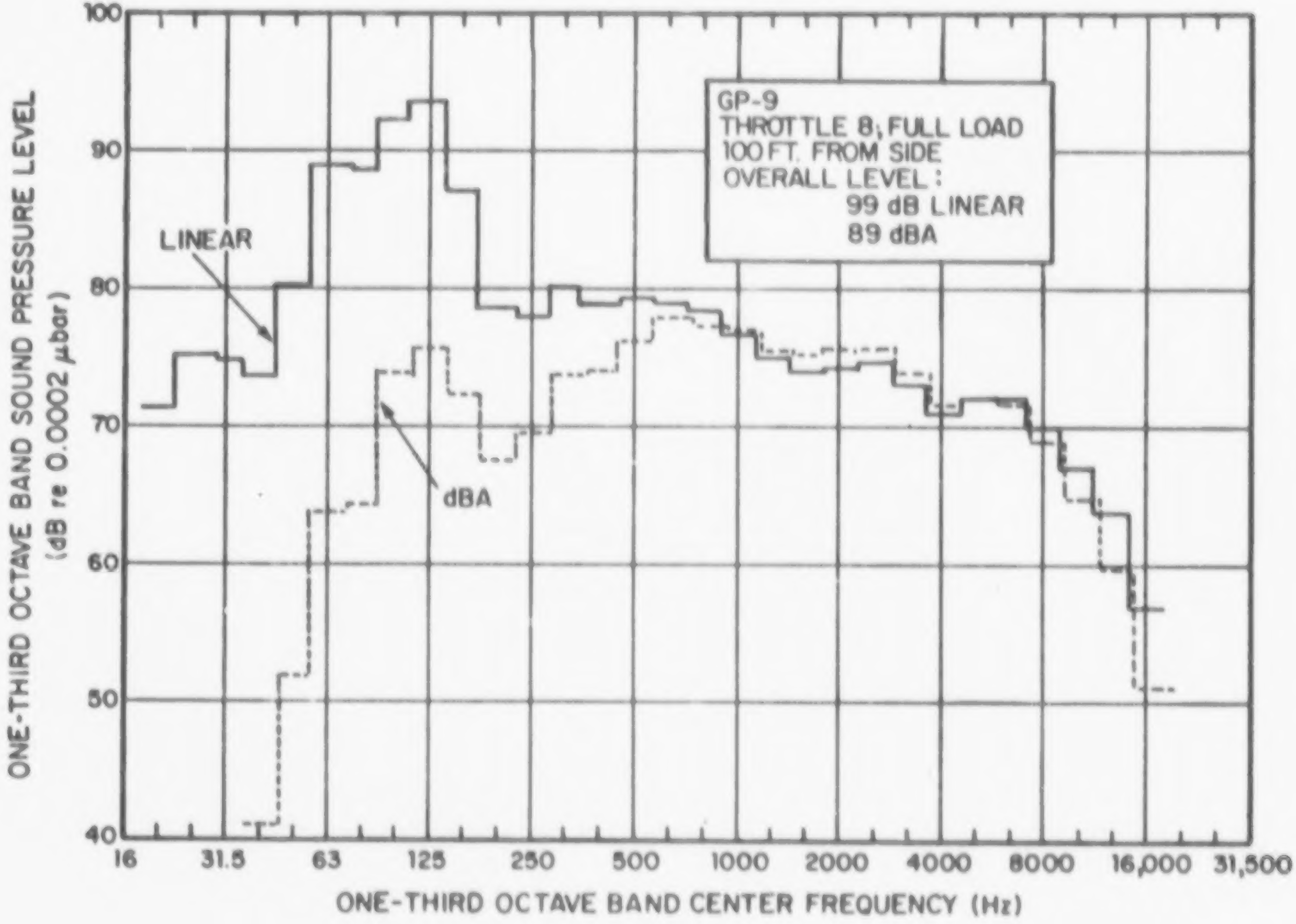


FIGURE B-5. GP-9, THROTTLE 8, FULL LOAD, AT 100 FT.

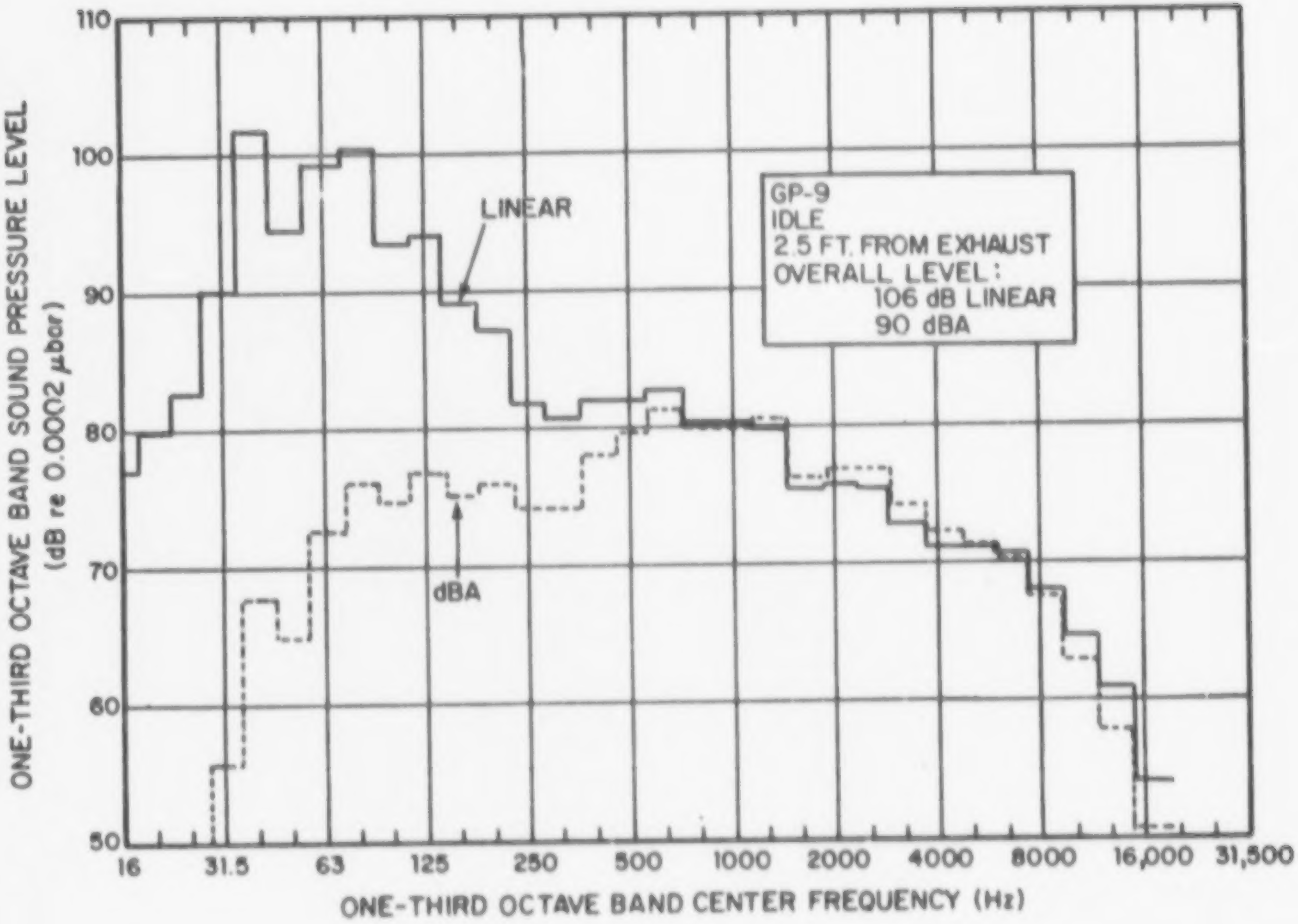


FIGURE B-6. GP-9, IDLE, AT 2.5 FT.

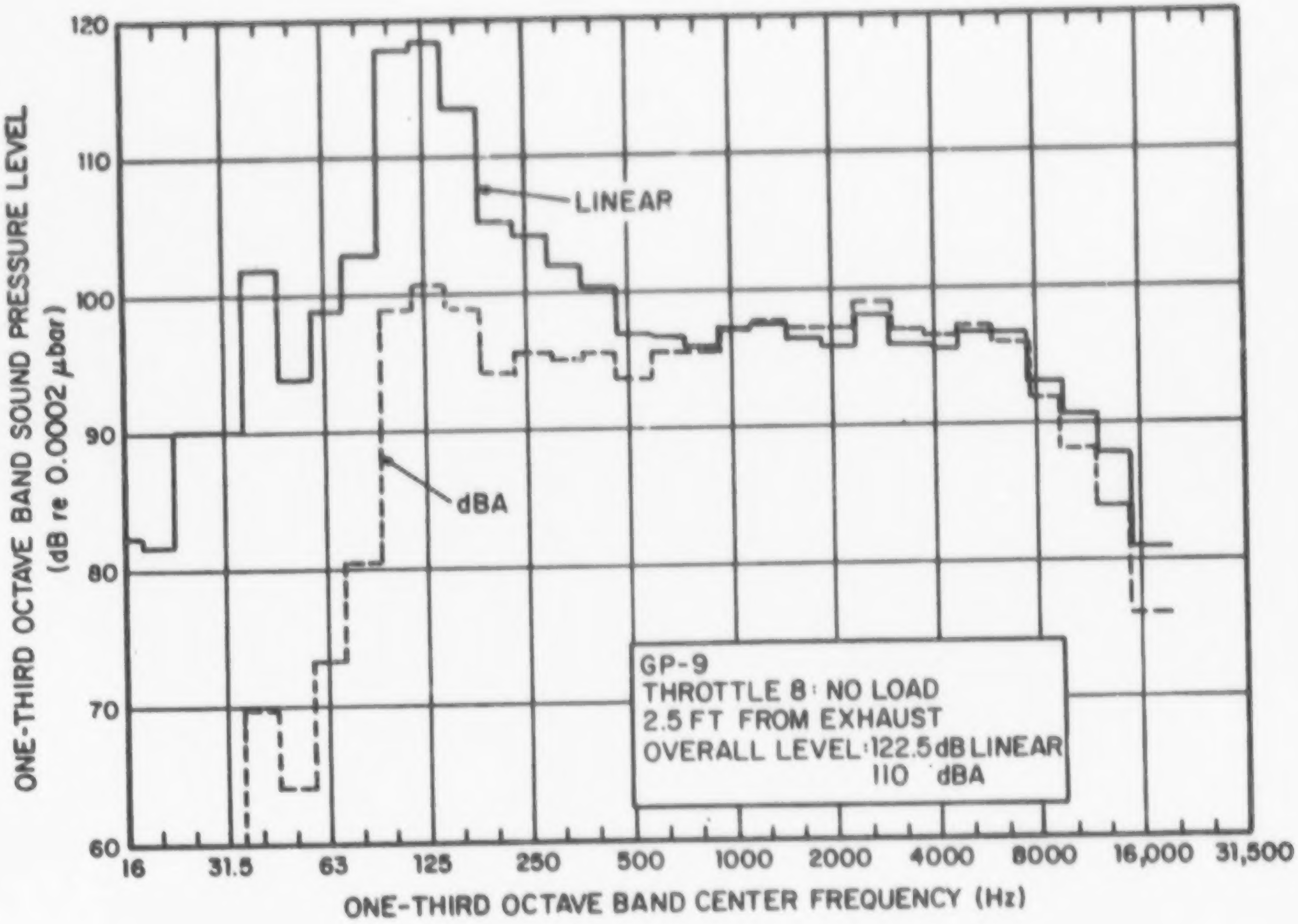


FIGURE B-7. GP-9, THROTTLE 8, NO LOAD, AT 2.5 FT.

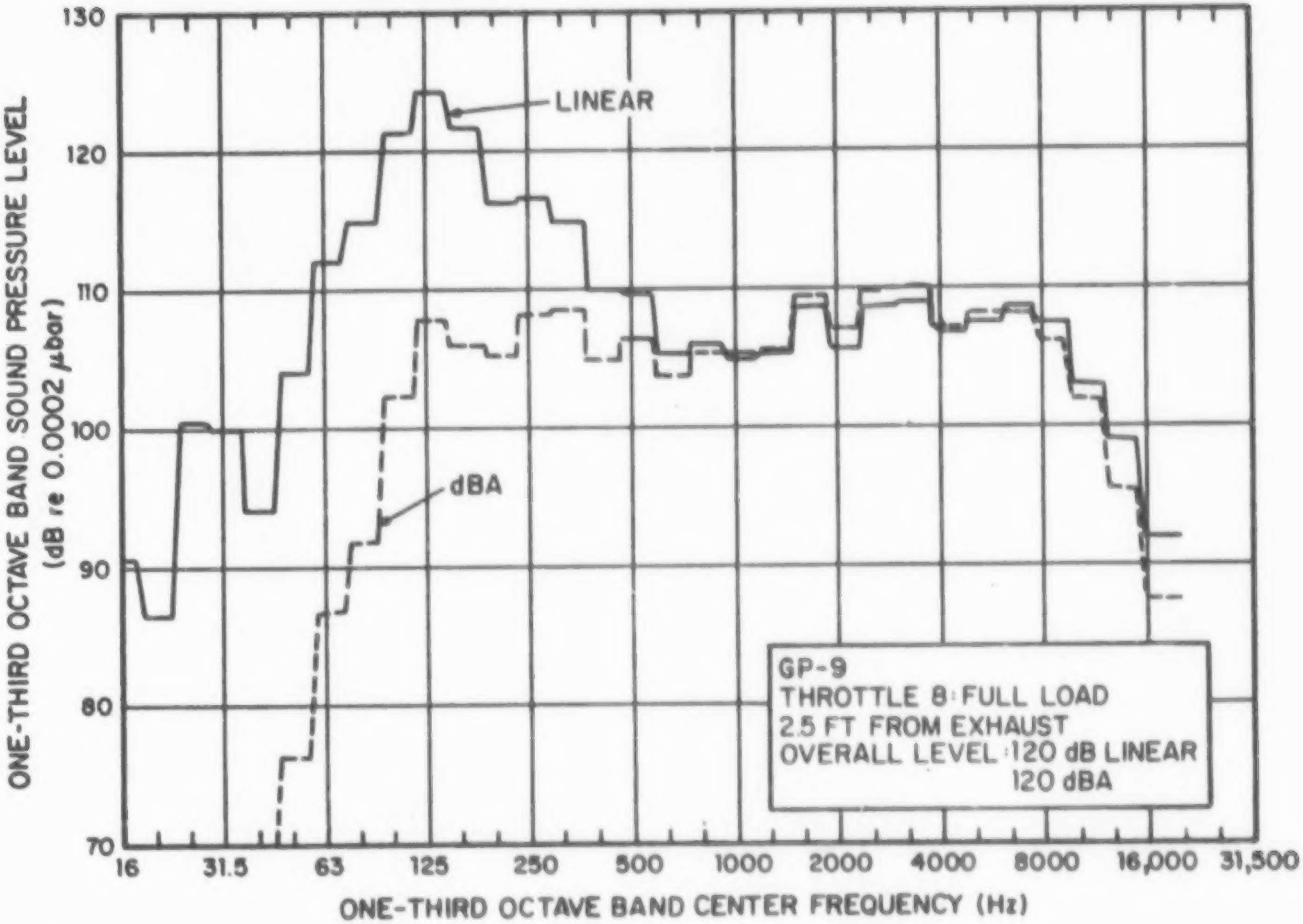


FIGURE B-8. GP-9, THROTTLE 8, FULL LOAD, AT 2.5 FT.

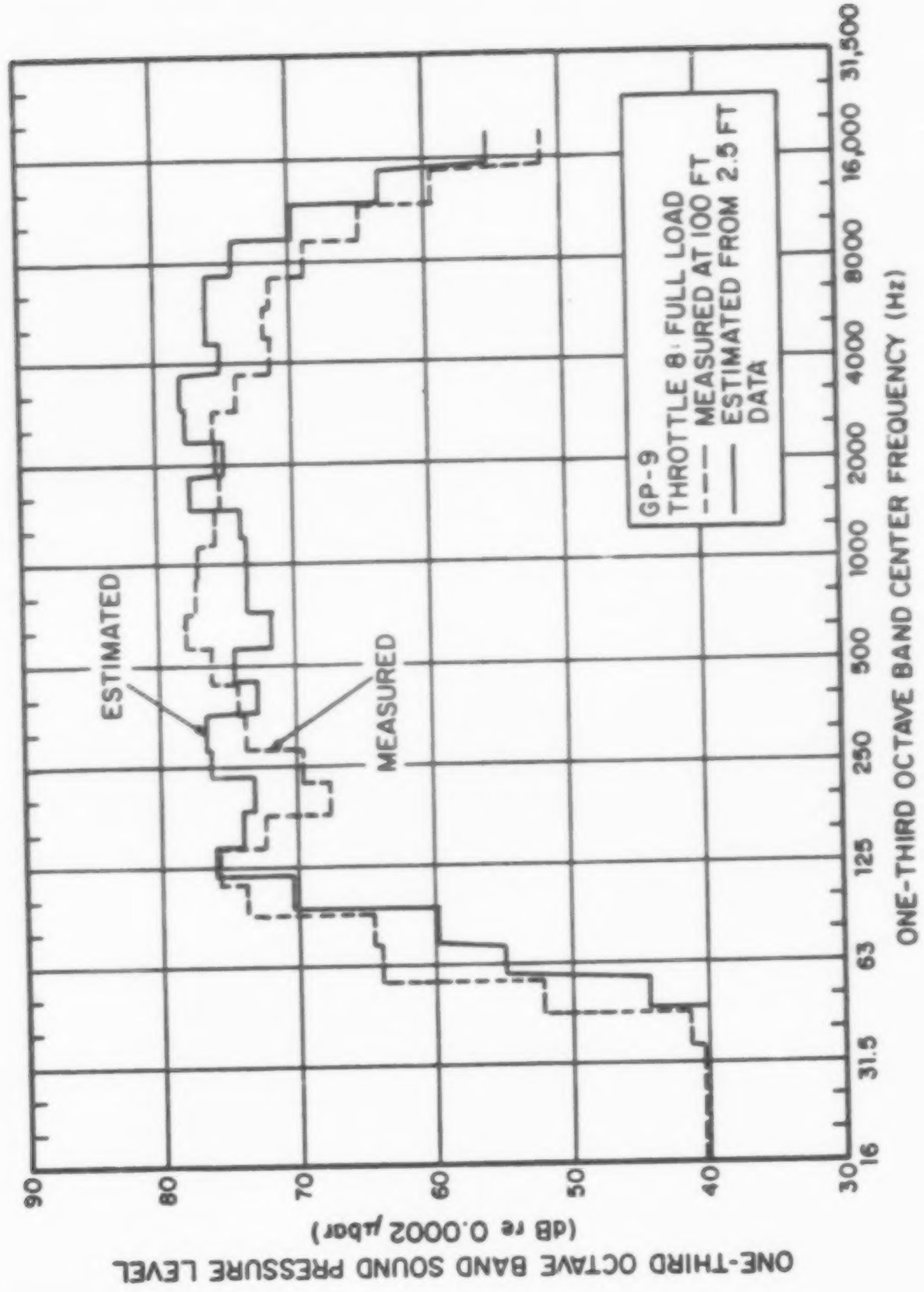


FIGURE B-9. COMPARISON OF ESTIMATED AND ACTUALLY MEASURED NOISE SPECTRA.

APPENDIX L

TRIP TO MONTREAL LOCOMOTIVE WORKS

On October 2, 1974, BBN personnel traveled to Montreal, Canada to visit the Montreal Locomotive Works (MLW), formerly a division of Alco Products but presently owned (52 percent of its stock) by Studebaker-Worthington. Though MLW owns all Alco Products' engineering designs, the firm presently manufactures locomotives of its own design, primarily for customers outside of the United States. The purpose of the visit was to measure the noise from an M-420 diesel electric locomotive and also to gather information on Alco locomotives no longer manufactured but still operating in the U.S.

M-420 Noise Measurements

Although completely an MLW design, the M-420 diesel electric locomotive is similar to the old Alco Century Series C-420 in that the same Alco 251 series 2000-hp turbocharged 12-cylinder diesel engine is used as the power plant (MLW manufacturers engines under license from Alco Engines Division of White Industrial Power Inc., the surviving corporate identity of the original Alco Products Corporation). However, the M-420 and C-420 use different trucks, and the operator's compartment and the front (short) hood are slightly different (see figure D-1.)

Although the C-420 and the M-420 are slightly different in appearance, the stationary noise from the M-420 should be representative of the C-420 because the two locomotives used the same power plant.

With the aid of Richard Cooper of MLW, measurements of the noise from the M-420 locomotive were made in the yard behind the MLW plant on October 3, 1974 between the hours of 9:30 a.m. and 11:00 a.m. EDT.

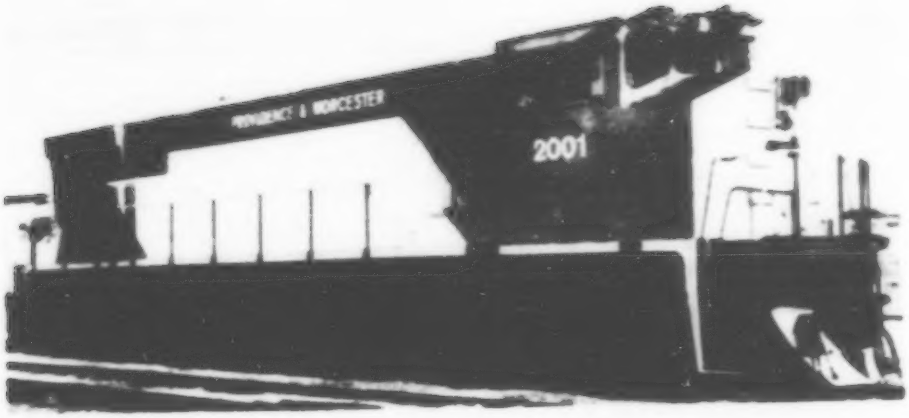

PROVIDENCE & WORCESTER
2001

FIGURE D-1. M-420 DIESEL ELECTRIC LOCOMOTIVE.

The following measurements were performed:

1. The overall A-weighted sound pressure level was measured at 100 ft from the locomotive at idle and at throttle 8 under full load.

2. The unweighted sound pressure level was recorded at 100 ft from the locomotive at throttle 8 under full load.

3. The unweighted sound pressure level was recorded at 2.5 ft from the exhaust stack, as shown in figure D-2, with the locomotive at idle and at throttle 8 under full load.

Because of the short cables from the resistor bank used to load the locomotive, the M-420 could not be moved to a location completely free from all reflecting surfaces. Figure D-3 shows the location of the locomotive, the measurement position, and the significant reflecting surfaces (buildings etc.). The overall A-weighted sound pressure levels are shown in Table D-1. These measurements were made with a B&K #4145 1-in. microphone (Ser. No. 259175) with foam wind screen connected to a B&K No. 2203 Sound Level Meter (SLM) (Ser. No. 151612).

TABLE D-1

M-420 NOISE LEVELS AT 100 FT

	Position 1	Position 2
Throttle 8	85 – 87 dBA	87 – 92 dBA
Idle	64 – 65 dBA	63.5 – 64.5 dBA

The sound level meter was in the "fast" A-weighted setting.

The 3- to 5-dBA increase in noise measured at Position 2 was probably due to reflections from the corrugated metal building shown in figure D-3. Because Position 1 is more removed from all

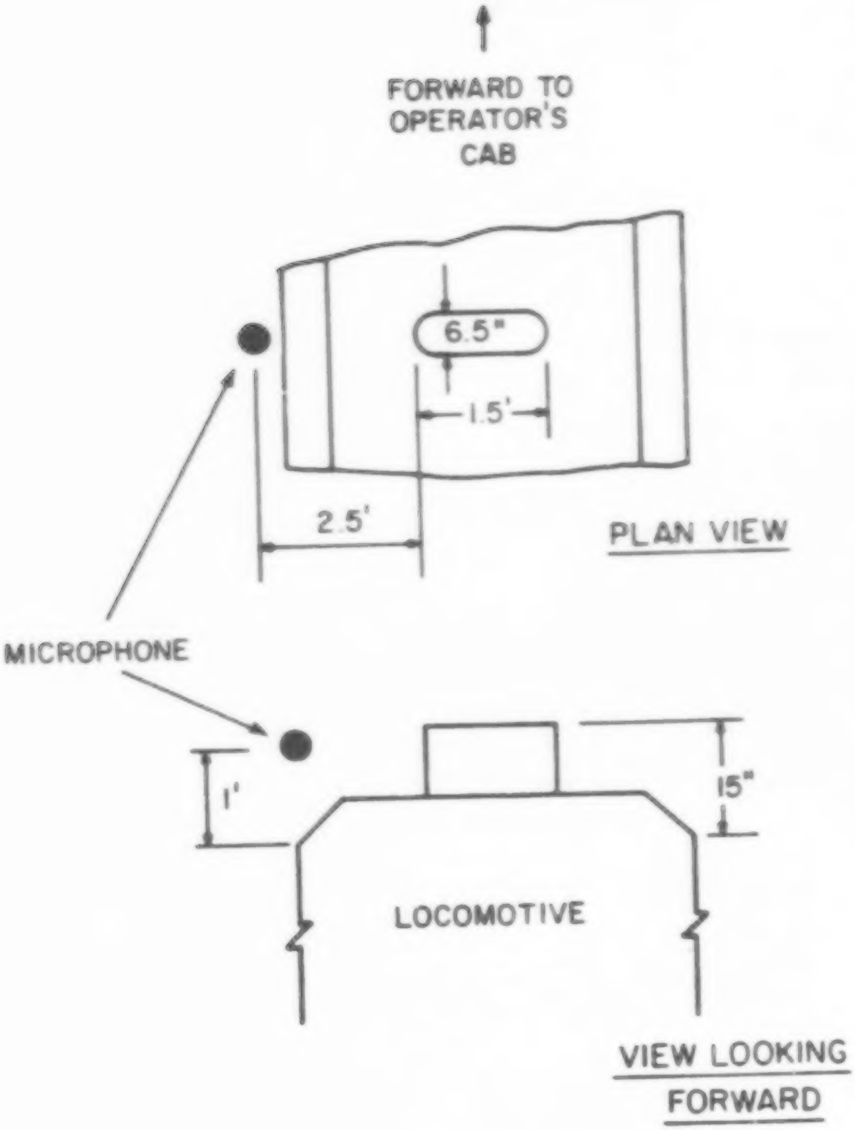

FORWARD TO OPERATOR'S CAB
6.5"
1.5'
2.5'
PLAN VIEW
MICROPHONE
1'
15"
LOCOMOTIVE
VIEW LOOKING FORWARD

FIGURE D-2. NEARFIELD MICROPHONE LOCATION.

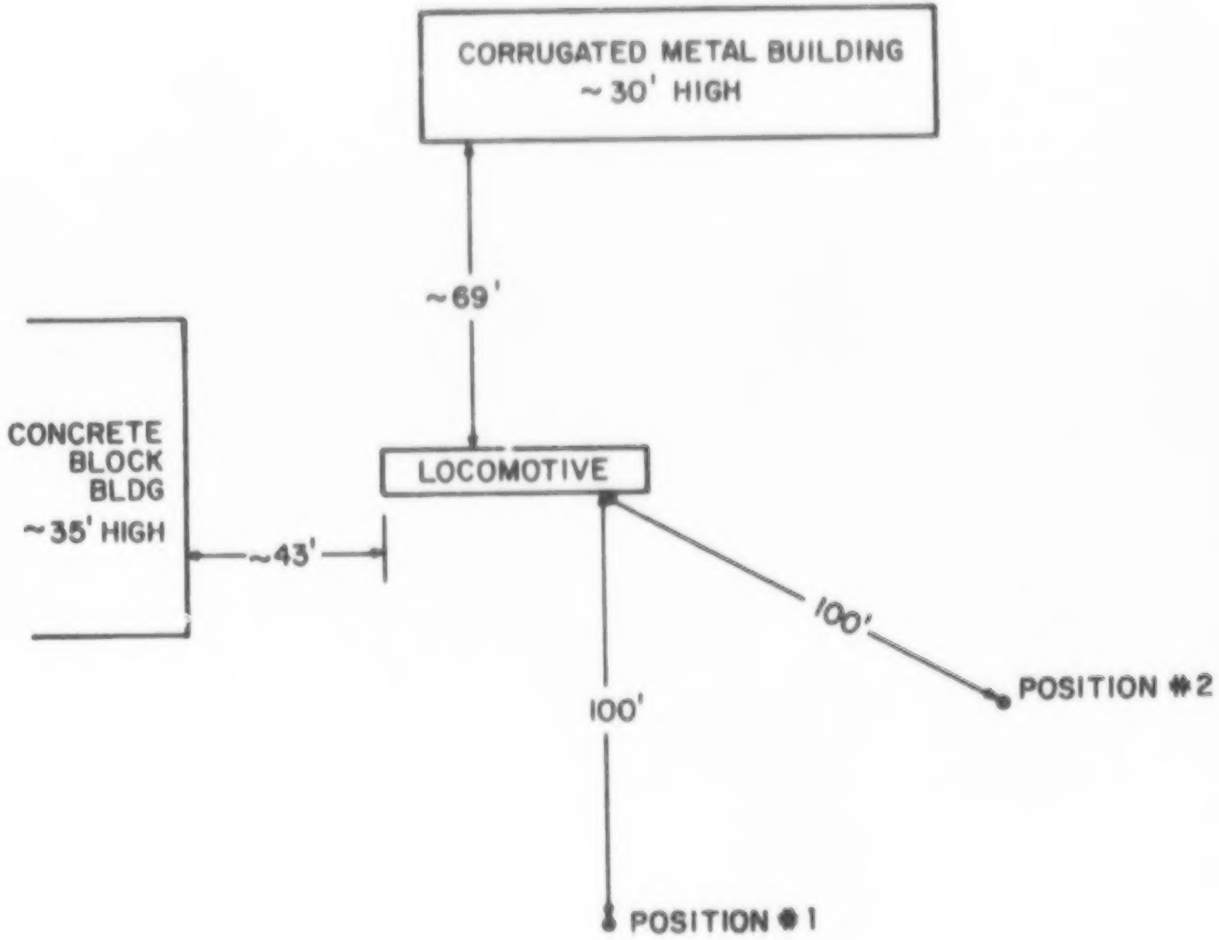

CORRUGATED METAL BUILDING
~30' HIGH
~69'
CONCRETE
BLOCK
BLDG
~35' HIGH
~43'
LOCOMOTIVE
100'
100'
POSITION #2
POSITION #1

FIGURE D-3. M-420 NOISE MEASUREMENT LOCATIONS.

reflecting surfaces, the levels measured there are more representative of the noise produced by the locomotive.

With the same microphone windscreen and SLM, recordings of the noise were made by connecting the output of the SLM to a Kudelski Nagra III (Ser. No. B-61-1107) single-track tape recorder. The SLM was in the fast linear setting. The recordings were later reduced in the BBN laboratory in Cambridge, Mass. under a Federal Scientific UA-500 Ubiquitous Spectrum Analyzer. The data are displayed in figures D-4 through D-7.

We had hoped to use the narrowband analysis of figure D-6 to compare exhaust and cooling fan noise levels by comparing the peak levels at the appropriate frequencies; i.e., firing frequency and blade passage frequency. The necessary data to calculate the firing and blade passage frequency are given in Table D-2 (courtesy of Bud Parker of MLW).

TABLE D-2

M-420 ENGINE AND COOLING FAN DATA

Engine RPM at throttle 8	1050
Engine RPM at idle	400
Number of cylinders	12 (4 strokes/cycle)
Number of fan blades	6
Fan speed	
• top speed	1.31:1 speed increase over engine ~ 10 percent slip in clutch or less
• intermediate speed	1.31:1 speed increase over engine RPM 50 percent to 60 percent slip in clutch
Fan diameter	66 in.

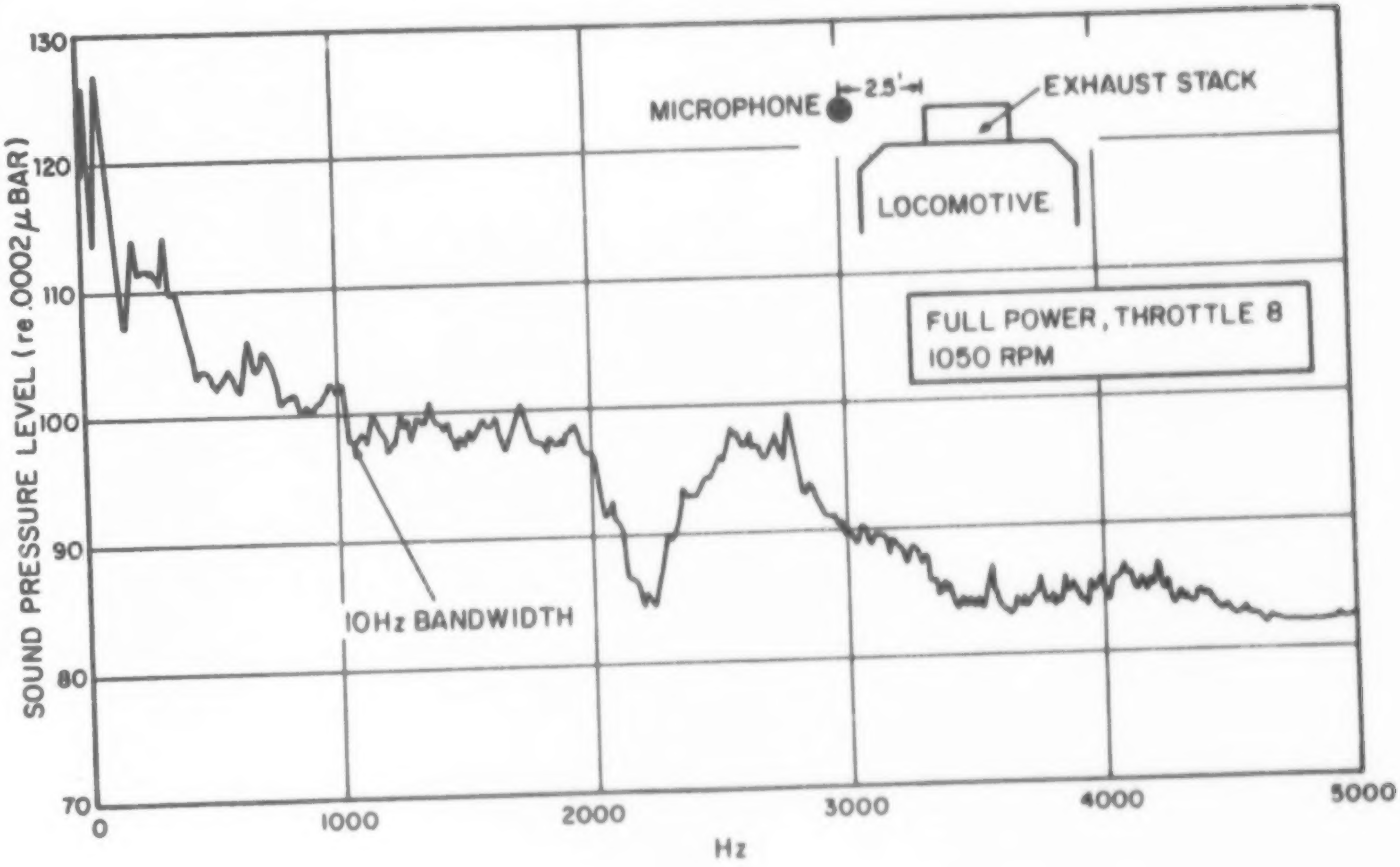


FIGURE D-4. FULL POWER, THROTTLE 8, 1050 RPM.

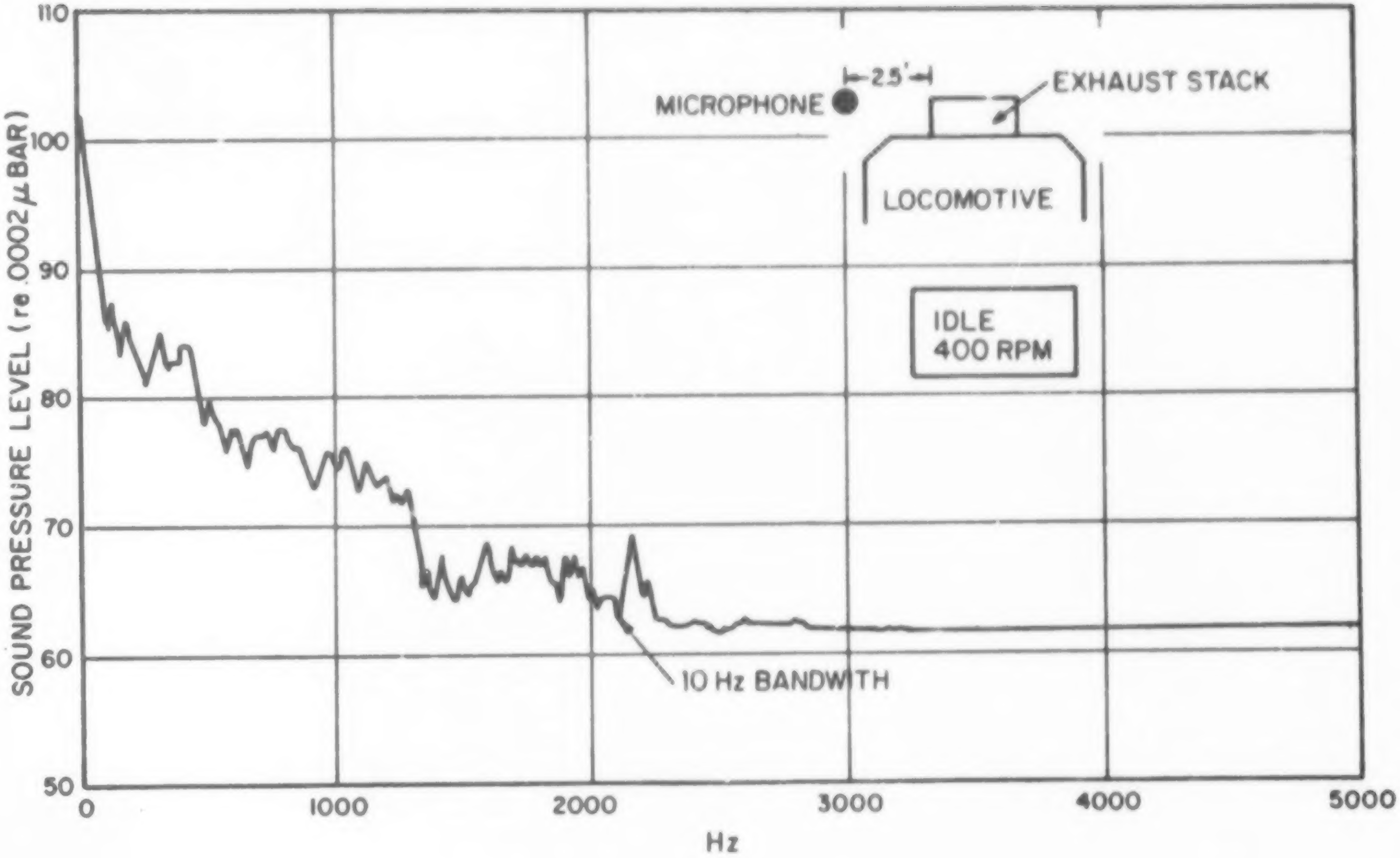


FIGURE D-5. IDLE, 400 RPM.

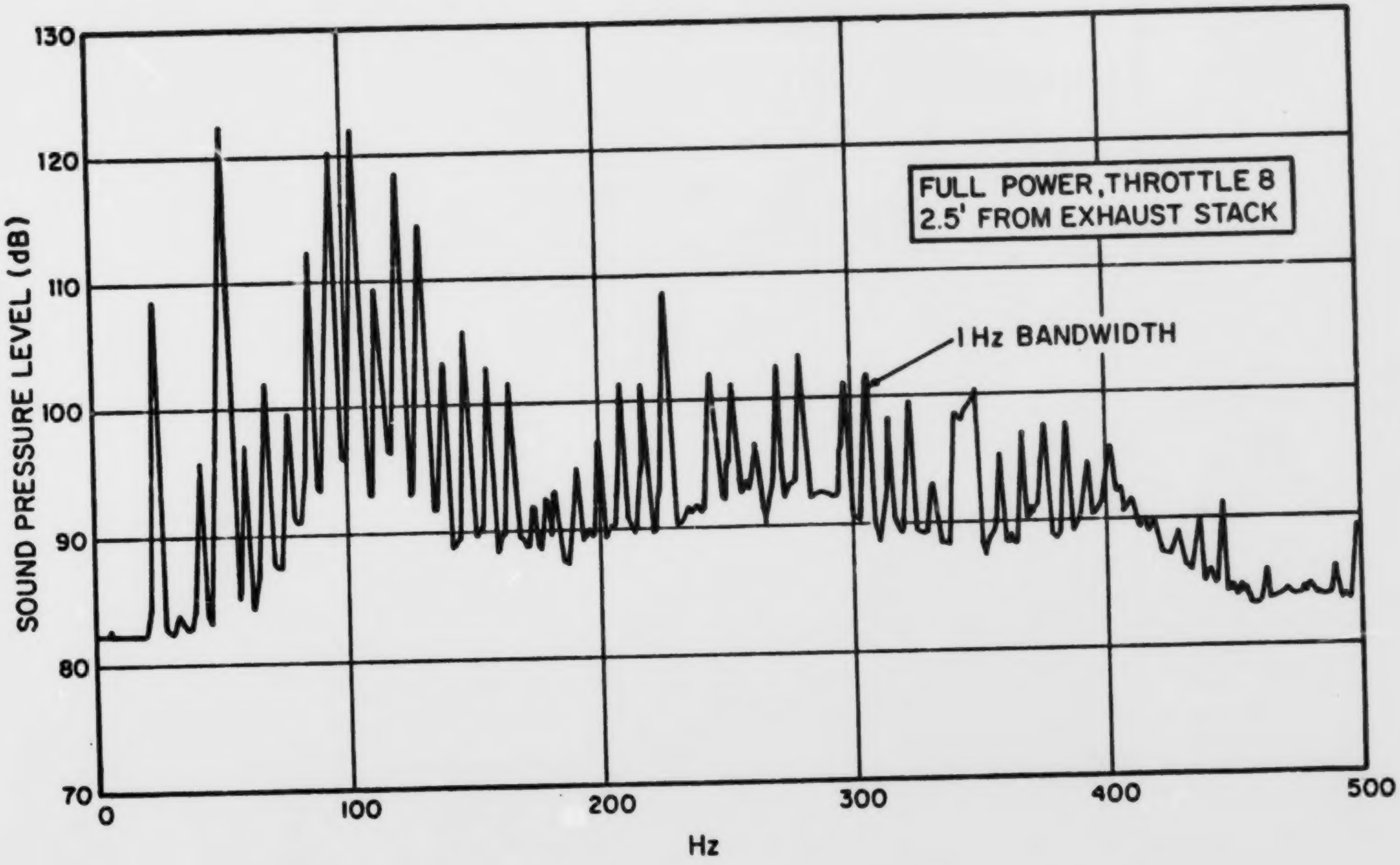


FIGURE D-6. FULL POWER, THROTTLE 8, 2.5 FT FROM EXHAUST STACK.

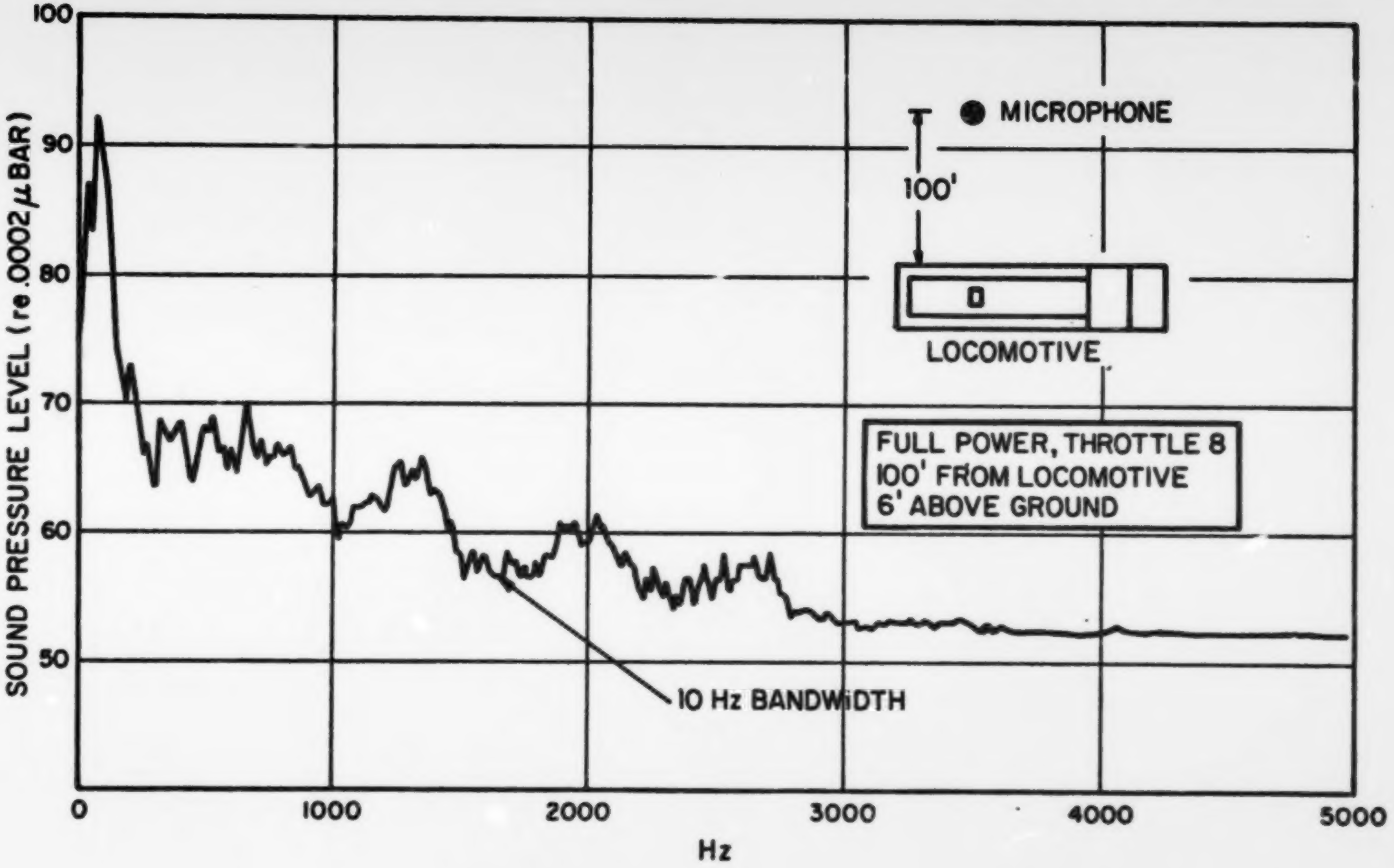


FIGURE D-7. FULL POWER, THROTTLE 8, 100 FT FROM LOCOMOTIVE.

The figures computed from these data are shown in Table D-3.

TABLE D-3

FIRING AND BLADE PASSAGE FREQUENCY DATA

Firing frequency	= 105	Hz
Top-speed Blade Passage frequency	= 124	Hz
Intermediate-speed Blade Passage frequency	= 55 – 69	Hz

Unfortunately, there are two possible fan speeds, depending on the heat load on the engine. An electromagnetic clutch between the engine and the fan produces some uncertainty in the speed reduction through that clutch. The resulting uncertainty in the blade passage frequency and the profusion of lines in figure D-6 make it difficult to trace the fan noise lines in the spectrum without an elaborate and careful analysis in which each line in the figure is identified.

Information on Alco Locomotives

With the help of Hugh Paton, Vice President of Engineering at MLW, we reached Robert Bergner, formerly employed by Alco Products in Schenectady, New York, and presently employed by MLW in Montreal. Mr. Bergner was very familiar with all of the locomotives that are of interest to us. A summary of his comments follows.

1. For all Alco low-hood switchers or road switchers, there is room for a muffler above the hood directly above the engine.*

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*On the S-1, S-2, S-3, S-4, and T-6 switchers, this area is approximately 2 ft high by 6 ft wide by 22 ft long.

Visibility problems can be minimized by mounting the muffler as far aft on the hood (near the radiator) as possible without interfering with the cooling fan air flow. The locomotives that fit in this category are all the Alco switchers, the T-6, RS-1, RS-2, RS-3, RSC-2, RSD-4, and RSD-5.

2. The muffler above the hood would present some additional maintenance problems, since piston and cylinder liner removal is presently done through a trap door in the top of the hood on all in-line 6-cylinder engines. As a result, the muffler would have to be removed before this major maintenance could be performed on any Alco switcher and the T-6, RS-1, and RSD-1 locomotives.

3. For all high-hood Alco road switchers without dynamic brakes, there is considerable space under the hood between the engine and the roof of the hood.* Figure D-8 shows this space on the M-420 locomotive, looking aft from the generator to the turbocharger. If these locomotives have the dynamic brake option, however, this space is used for the dynamic brake resistor assembly. As a result, muffler placement will be difficult on the RS-11, RSD-12, RSD-15, C-420, C-424, C-425, and C-430 locomotive with the dynamic brake option.†

4. For the larger Century Series locomotives, the C-628, C-630, and C-636, the dynamic brakes are in a compartment separate from the engine and, as a result, the space above the engine is always available for a muffler.

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*On the C-420 locomotive there is, conservatively, a space approximately 12 ft long, 1 ft high, and about 3 ft wide above the engine. It may not be possible to utilize the 3-ft width over the full height of the space; i.e., the muffler may have to be V-shaped so as not to interfere with cylinder liner or piston removal.

†Approximately 148 C-420, C-424, C-425, and C-430 locomotives out of 274 were built with the dynamic brake options.

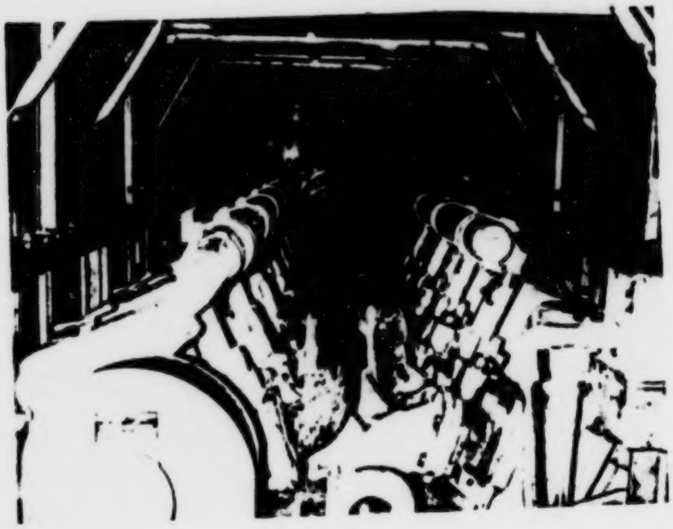


FIGURE D-8. SPACE IN THE ENGINE COMPARTMENT OF THE M-420 SUITABLE FOR THE INSTALLATION OF A MUFFLER.

The Use of Mufflers on Large Diesel Engines in Nonrailroad Applications: Results of a BBN Survey

Previous work made clear to us at BBN that little is known about the possible effects of mufflers on locomotive diesel engine performance. This lack of information, we suspected, resulted from the rarity of mufflers on locomotives. We reasoned that we might obtain such information from industries, other than railroads, which use large diesel engines and in which mufflers are more common. Accordingly, we conducted an informal survey of users, suppliers, and rebuilders on the influence of mufflers on engine operations. We did not discuss the acoustic performance of mufflers, since this subject is well documented in the case of nonrailroad diesel installations.

Our conclusions are:

Mufflers are used in marine and stationary power plant application in conformance with the backpressure recommendations of the engine manufacturers. There is no evidence that use of mufflers in such applications causes decreased engine life or reduced performance.

No information publicly available provides a technical rationale for the exhaust backpressure limitations (5-in. H_2O for turbocharged engines) which EMD specifies.

The technology exists to produce turbochargers to withstand temperatures up to 1500°F, but units in present production withstand temperatures up to 1200°F only.

No nonproprietary test data on the effects of high backpressure mufflers on emissions, engine reliability, or efficiency are available at this time.

The survey was conducted primarily by telephone, with appropriate letter follow-ups. There were two groups of interviews. The first group, 10 interviews, was with people involved with marine applications of diesel engines. These people were asked what effects muffler-induced exhaust backpressure had on efficiency, power, emissions, reliability, and noise, and what sizes of mufflers were used on their engines. The second group of interviews was with four persons responsible for manufacturing exhaust system manifolds and turbochargers. These people were asked to provide information on the state of the art of materials and the reliability of components to be used at temperatures above those now common diesel electric locomotives. Summaries of those interviews which yielded useful information follow.

INTERVIEW SUMMARIES:

George Ponton
Hyattsville, Maryland
Former engineer with
Nashville Bridge Co.
Nashville, Tenn.

Nashville Bridge designs and builds diesel-powered tow boats. Mr. Ponton reported that tow boats are gneerally equipped with spark arresters and sometimes with mufflers. (Sparks are considered at least as much as problem on boats as around railroads). Mr. Ponton said that when mufflers are used, they are sized to avoid backpressures in excess of those specified by the engine manufacturer. No independent muffler design is attempted by the boat builder. He mentioned Maxim Silencer Company and Burgess Manning Company as two major suppliers of mufflers for large diesel engines.

James Gunlauch, Vice President
Canal Barge Line
New Orleans, La.

Canal Barge Line operates diesel tow boats. Mr. Gunlauch said that operators typically do not measure exhaust backpressure on their boats; they assume that the designer has designed the exhaust system properly.

The total amount of fuel used by a tow boat is known, but the power delivered by the engines is typically not measured. Therefore, the effect on engine efficiency of different mufflers is not known. Canal Barge has not attempted to correlate muffler use with engine failures and has made no measurements of engine emissions.

R.B. Gladstone, Manager-Government Sales
General Motors - Electromotive Division
La Grange, Ill.

Mr. Gladstone sent us copies of pertinent pages of EMD's Marine Applications Book; figure 8-1 shows a page describing mufflers specified for EMD 645 series diesel engines.

Mr. Gladstone reaffirmed the previously stated limitations on engine backpressure and said that use of higher backpressure could void the engine warranty. He did not know about effects of mufflers on emissions or efficiency.

Robert Fortenbury, Salesman
Sample Brothers
New Orleans, La.

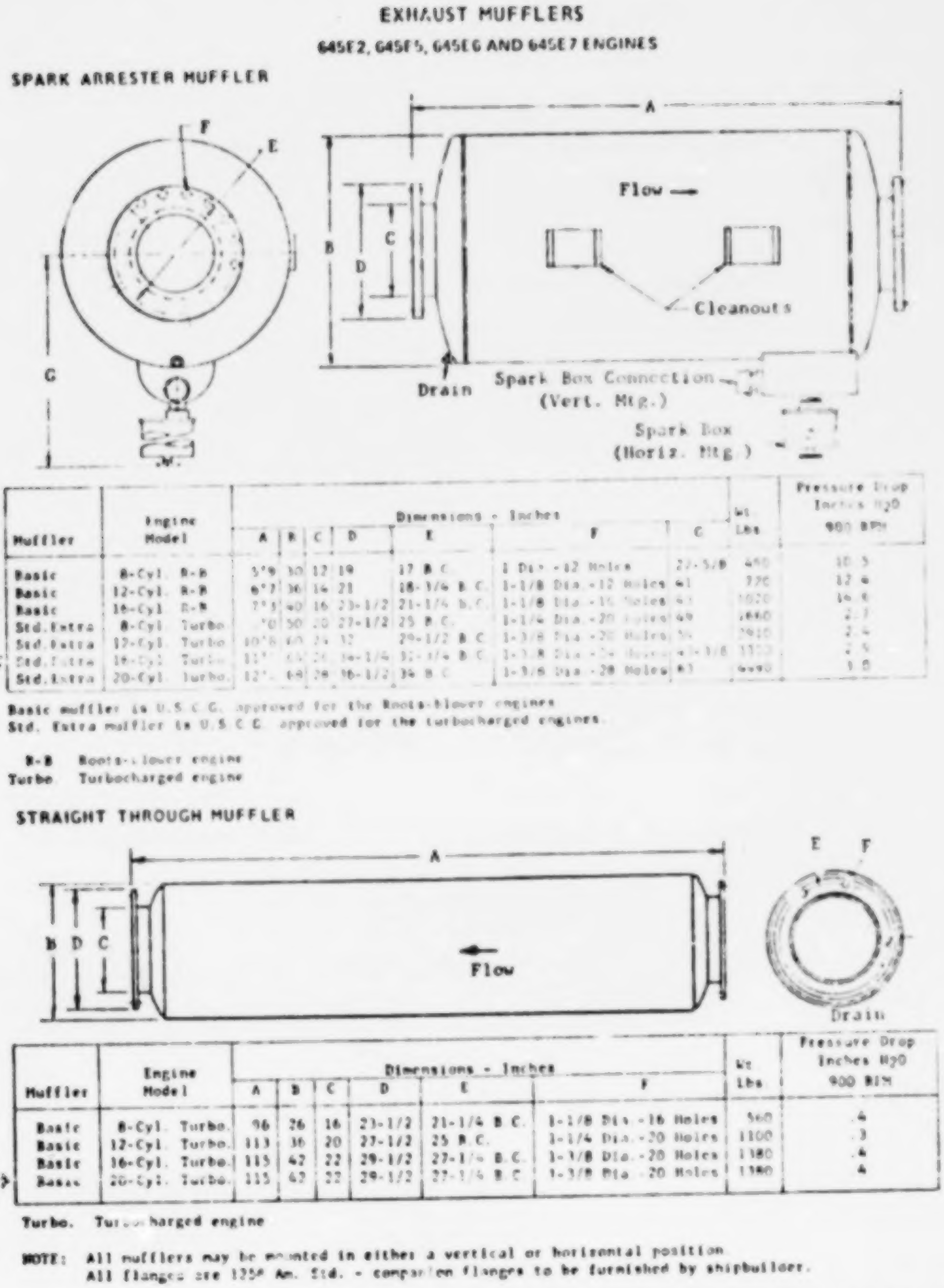
Sample Brothers markets industrial mufflers. Mr. Fortenbury said that mufflers used on EMD 645 E-5 engines typically have a 28-in. inlet diameter and provide 5- to 6-in. H_2O of total backpressure at the exit of the turbocharger.

Gerrit Van Dissel, Naval Architect
Potter & McArthur Inc.
Watertown, Mass.

Mr. Van Dissel has designed numerous boats using EMD diesels fitted with mufflers and spark arresters. He considers these standard items and is not aware of any detrimental effects on performance.

C.M. Bennett
Precision National Corp.
Mt. Vernon, Ill.

Precision National is a major engine rebuilder. Mr. Bennett said that since his firm does not measure engine operating parameters on boats, he does not know the effects of muffler backpressure. He has not seen any engine failures which could be traced to high exhaust backpressure.


F
E
G
B
C
D
A
Flow
Cleanouts
Drain
Spark Box Connection
(Vert. Mtg.)
Spark Box
(Horiz. Mtg.)
A
B D C
Flow
E F
Drain

EXHAUST MUFFLERS

645E2, 645E5, 645E6 AND 645E7 ENGINES

SPARK ARRESTER MUFFLER

Muffler	Engine Model	Dimensions - Inches							Wt. Lbs.	Pressure Drop Inches H2O 900 RPM
		A	B	C	D	E	F	G		
Basic	8-Cyl. R-B	5'9	30	12	19	17 B.C.	1 Dia.-12 Holes	27-5/8	450	10.5
Basic	12-Cyl. R-B	6'7	36	14	21	18-3/4 B.C.	1-1/8 Dia.-12 Holes	41	770	12.6
Basic	16-Cyl. R-B	7'3	40	16	23-1/2	21-1/4 B.C.	1-1/8 Dia.-16 Holes	41	1020	14.8
Std.Extra	8-Cyl. Turbo	[illegible]'0	50	20	27-1/2	25 B.C.	1-1/4 Dia.-20 Holes	49	1660	2.7
Std.Extra	12-Cyl. Turbo	10'8	60	24	32	29-1/2 B.C.	1-3/8 Dia.-20 Holes	56	2910	2.4
Std.Extra	16-Cyl. Turbo	11'	64	26	34-1/4	32-1/4 B.C.	1-3/8 Dia.-24 Holes	61-3/8	3310	2.5
Std.Extra	20-Cyl. Turbo	12'-	68	28	36-1/2	34 B.C.	1-5/8 Dia.-28 Holes	61	4490	1.8

Basic muffler is U.S.C.G. approved for the Roots-blower engines.
Std. Extra muffler is U.S.C.G. approved for the turbocharged engines.

R-B Roots-blower engine
Turbo Turbocharged engine

STRAIGHT THROUGH MUFFLER

Muffler	Engine Model	Dimensions - Inches						Wt. Lbs.	Pressure Drop Inches H2O 900 RPM
		A	B	C	D	E	F		
Basic	8-Cyl. Turbo.	96	26	16	23-1/2	21-1/4 B.C.	1-1/8 Dia.-16 Holes	560	.4
Basic	12-Cyl. Turbo.	113	36	20	27-1/2	25 B.C.	1-1/4 Dia.-20 Holes	1100	.3
Basic	16-Cyl. Turbo.	115	42	22	29-1/2	27-1/4 B.C.	1-3/8 Dia.-20 Holes	1380	.4
Basic	20-Cyl. Turbo.	115	42	22	29-1/2	27-1/4 B.C.	1-3/8 Dia.-20 Holes	1380	.4

Turbo. Turbocharged engine

NOTE: All mufflers may be mounted in either a vertical or horizontal position.
All flanges are 125# Am. Std. - companion flanges to be furnished by shipbuilder.

FIGURE 8-1. SAMPLE PAGE FROM EMD MARINE APPLICATIONS DATA BOOK, SHOWING MUFFLERS RECOMMENDED FOR 645E SERIES DIESEL ENGINES.

Robert Gant
Preco Equipment Company
Houston, Texas

Preco is a rebuilder of diesel engines. Mr. Gant did not know of any data taken on tow boats relevant to engine performance as affected by mufflers.

INTERVIEW SUMMARIES: TURBOCHARGER MANUFACTURERS

Howard Bach. Manager-Turbocharger Marketing
Elliot Company, a Division of Carrier Corp.
Jeannette, Pa.

Elliott Company supplies turbochargers to General Electric and to De Laval. Mr. Bach was asked to discuss presently allowable operating temperatures for turbochargers, future trends in turbocharger temperatures, and the costs of manufacturing and servicing turbochargers for higher temperatures. He indicated that the costs of components and servicing for turbochargers designed to operate at 1200°F turbine inlet temperature and 10-in. H_2O backpressure are the same as the cost for a unit designed to operate at 900°F. (Absolute manufacturing costs are not available.) Elliott is testing prototype turbine and nozzle ring components at 1350°F with limited success. The cost of these components is estimated to be 3 to 4 times as high as for the present production components. Table 8-7 summarizes the cost information provided by Mr. Bach.

The backpressure limitation of 10-in. H_2O seems to be set by a lack of experience at higher backpressures. When questioned about the factors which limit the backpressure recommendations, Mr. Bach indicated that lower pressure difference causes bearing seals to leak, for example, when a locomotive is at high altitudes. There is apparently no experimental substantiation for the 10-in. H_2O level which they recommend.

TABLE 8-7

RELATIVE COMPONENT AND SERVICING COSTS FOR TURBOCHARGERS AS A FUNCTION OF DESIGN TEMPERATURE

Inlet Temperature to Turbocharger	900°F	1000°F Production	1100°F Production	1200°F Production	1300°F Prototype	1350°F Prototype	1400°F	1500°F
Relative Turbine Cost	1	(1)	(1)	(1)	(3-4)	(3-4)	(NA)	(NA)
Relative Housing Cost^2	1	(1)	(1)	(1)	(NA)	(NA)	(NA)	(NA)
Relative Servicing Interval for Turbine and Bearings	1	(1)	(1)	(1)	(NA)	(NA)	(NA)	(NA)
Relative Service Life of Housing	1	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)
Relative Cost of Servicing	1	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)

Turbocharger Outlet Pressure Above Atmospheric	0"H_2O	5"H_2O	10"H_2O	15"H_2O	20"H_2O
Relative Turbine Cost	1	(1)	(1)	(NA)	(NA)
Relative Housing Cost	1	(1)	(1)	(NA)	(NA)
Relative Servicing Interval for Turbine and Bearings	1	(1)	(1)	(NA)	(NA)
Relative Service Life of Housing	1	(1)	(1)	(NA)	(NA)
Relative Cost of Servicing	1	(NA)	(NA)	(NA)	(NA)

1. Source: H. Bach, Elliot Company.
2. Present housing replacement rate is approximately 15% per year.

AMTRAK Experience with Muffled Locomotives

In 1973, the National Railroad Passenger Corporation (AMTRAK) took delivery of forty EMD SDP-40F locomotives fitted with Universal Silencer exhaust mufflers. These units have been operating in the Western District at an average rate of approximately 200,000 miles per year. We talked to Mr. Deane Ellsworth, manager of the Mechanical Systems Department of AMTRAK about service experience with these mufflers.

The locomotive price differential due to the muffler was \$500 to \$600, exclusive of carbody modifications. The muffler's space requirements dictate an overall engine height of 15 ft 9 in.; this height makes the locomotives unusable in the Baltimore Harbor Tunnel or Union Station, Washington, D.C. Wyle Laboratories has made noise level measurements for EMD, which now retains those data.* Mr. Ellsworth's recollection was that typical levels were 66.5 dBA at idle and 88 to 89 dBA at full throttle.

To date, AMTRAK has experienced no service problems which could be related to mufflers. There have been no locomotive road failures. There have been no muffler-induced engine maintenance problems; as yet, however, AMTRAK has not had to remove the turbochargers, so the muffler's effect on engine accessibility has not been evaluated. No increase in fuel consumption levels have been noted; on the other hand, it would be difficult to measure changes as small as 1 percent. There have been no turbocharger failures or replacements to date, so the effect of backpressure on turbocharger life cannot be evaluated.

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*An earlier telephone conversation with Mr. R. Pribramsky of EMD indicated that any data which they would make available would be given directly to EPA at the Agency's request.

Appendix O

REFRIGERATOR CARS

Noise From Refrigerators and Auxiliary Engines

BBN has reviewed the data on noise levels produced by refrigeration units on cold-storage cars and by auxiliary engines on passenger locomotives. The work summarized data available in reports and other sources; no original measurements were made.

Refrigerator Cars. There are 26,000 refrigerator cars in the United States, half of which are owned by one company (Pacific Fruit Express Company of San Francisco). The refrigeration units on the cars are powered by 2- or 3-cylinder Detroit Diesel engines running at 800 or 1200 rpm. These engines run continuously to cool the cargo.

Our primary source of noise data for refrigerator cars is Wyle Laboratories Report WCR-73-5 (1973). Table 8-8 lists noise levels of four cars at a 50-ft distance. Note that, assuming 6-dB attenuation per doubling of distance, only the 3-cylinder units violate the 67-dB standard at 100 ft for a single car and then only on one side. However, refrigerator cars are usually made up into trains of 100 cars or more; at that size, the noise level of the train will exceed the 67-dB-at-100-ft standard. In addition, note that several of the measurements in Table 8-8 were actually made in the near field and were extrapolated to 50 ft. In these cases, further extrapolation to 100 ft may result in inaccuracies.

The data for the second car in Table 8-8 indicate that as much as 6 to 7 dB of noise reduction could be achieved by muffling the engine.

An additional noise measurement was obtained from Rickley, Quinn and Sussan (1974), who reported a level of 84.5 dBA at a distance of 50 ft from the engine side of a Boston & Maine refrigerator car. The model of diesel engine and the compressor manufacturer were not noted.

TABLE 8-8

MEASURED NOISE LEVELS OF FOUR CARS, 50-FT DISTANCE[*]

		Typical Noise Levels Emitted by Mechanical Refrigerator Cars		
			A-Weighted Noise Level in dB (re 20μN/m) at 50 ft	
Engine Model and Rated Power	Compressor Manufacturer	Operating Mode	Engine Side	Condenser Side
Detroit Diesel 2-71 80 hp	Trane	Low Throttle: 800 rpm High Throttle: 1200 rpm	69.5 76.5	66[†] 70.5[†]
	Carrier	Low Throttle: 800 rpm High Throttle: 1200 rpm	-- 75.5[†]	65 (66.5[†]) 71
		Diesel off – motor compressor driven by 220V auxiliary electrical power. High Setting	61[†]	64 (63[†])
Detroit Diesel 3-17 120 hp	Trane	High Throttle: 1200 rpm	80[†]	73.5[†]
Detroit Diesel 3-53 100 hp	Trane	High Throttle: 1200 rpm	80.5[†]	71.5[†]

[*] Source: Wyle Labs (1973).

[†] Calculated via nearfield measurement procedure and analytical technique.

Auxiliary Diesel Engines. Passenger locomotives and cars are frequently equipped with (1) diesel engines to drive an alternator supplying electric power to the train, and (2) steam generators (on the locomotive) to supply heat for the train. AMTRAK is purchasing new locomotives with auxiliary diesel engines on board; some of their club cars already have them.

Data on noise levels from auxiliary engines were provided by the Illinois Railroad Association in its submission to Docket No. ONAC 7201002; the IRA cited noise levels of two auxiliary engines as measured by the Chicago & Northwestern Railway. These engines were Cummins V-block diesels running at 1800 rpm so as to generate 60-Hz electricity. Noise measurements were taken with no load on the engines; they would have been higher if a load had been applied. The measured levels were 58 and 55 dBA at 100 ft from the locomotive.

APPLICABILITY OF TRACK AND RAIL SAFETY STANDARDS TO NOISE

Introduction

In this section, we comment on the DOT FRA Track Safety Standards* and Railroad Freight Car Safety Standards,† insofar as their enforcement affects noise.

Track Standards

Track standards limit train speed by assigning each track to a class, which is determined by the quality of track maintenance. Table 7-1 provides the maximum allowable operating speed (in mph) for each class.

TABLE 7-1

MAXIMUM ALLOWABLE OPERATING SPEED

Class	Maximum Allowable Speed (mph)	
	Freight Trains	Passenger Trains
1	10	15
2	25	30
3	40	60
4	60	80
5	80	90
6	110	110

Section 213.9 states "If a segment of track does not meet all of the requirements for its intended class, it is reclassified to

the next lowest class of track for which it does meet all of the requirements of this part." This provision, together with a schedule of fines for violations, puts teeth into the standard. A railroad can indeed operate on poorly maintained track - but only at inefficiently low speeds. Therefore it is in the railroads' interest to maintain track where high-speed operation is needed.

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*CFR Title 49, Part 213, Sec. 213.1 - 213.241, with Appendix B (Fed. Register, Vol. 39, No. 67, April 5, 1974).

†CFR Title 49, Part 215.

In this section, we evaluate the impact of various sections of Part 213 on the noise generated by trains. Each section is quoted, then followed by an explanation of its effect on noise.

§213.53 Gage

(a) Gage is measured between the heads of the rails at right angles to the rails in a plane five-eighths of an inch below the top of the rail head.

(b) Gage must be within the limits prescribed in Table 7-2.

TABLE 7-2

GAGE LIMITS

Class of Track	Track Gage of Tangent Track Must Be –		The Gage of Curved Track Must Be –	
	At Least	But Not More Than	At Least	But Not More Than
1	4 ft 8 in.	4 ft 9¾ in.	4 ft 8 in.	4 ft 9¾ in.
2 and 3	4 ft 8 in.	4 ft 9½ in.	4 ft 8 in.	4 ft 9¾ in.
4	4 ft 8 in.	4 ft 9¼ in.	4 ft 8 in.	4 ft 9½ in.
5	4 ft 8 in.	4 ft 9 in.	4 ft 8 in.	4 ft 9½ in.
6	4 ft 8 in.	4 ft 8¾ in.	4 ft 8 in.	4 ft 9 in.

§213.55 Alignment

Alignment may not deviate from uniformity more than the amount prescribed in Table 7-3.

TABLE 7-3

ALIGNMENT DEVIATION LIMITS

Class of Track	Tangent Track	Curved Track
	The Deviation of the Mid-Offset From 62-ft Line[1] May Not Be More Than	The Deviation of the Mid-Ordinate From 62-ft Chord[2] May Not Be More Than
1	5 in.	5 in.
2	3 in.	3 in.
3	1¾ in.	1¾ in.
4	1½ in.	1½ in.
5	¾ in.	⅝ in.
6	½ in.	⅔ in.

[1] The ends of the line must be at points on the gage side of the line rail, five-eighths of an inch below the top of the railhead. Either rail may be used as the line rail, however, the same rail must be used for the full length of that tangential segment of track.

[2] The ends of the chord must be at points on the gage side of the outer rail, five-eighths of an inch below the top of the railhead.

Effect

Variations in gage may result in lateral motion of the train, with possible impact of wheel flanges against rail heads and car sway with attendant rattle, etc. These types of noise mechanisms have not been investigated quantitatively, however, and can only be mentioned in qualitative terms.

§213.109 Crossties

(a) Crossties may be made of any material to which rails can be securely fastened. The material must be capable of holding the rails to gage within the limits prescribed in §213.53(b) and distributing the load from the rails to the ballast section.

(b) A timber crosstie is considered to be defective when it is:

(1) Broken through;

(2) Split or otherwise impaired to the extent it will not hold spikes or will allow the ballast to work through;

(3) So deteriorated that the tie plate or base of rail can move laterally more than one-half inch relative to the crosstie;

(4) Cut by the tie plate through more than 40 percent of its thickness; or

(5) Not spiked as required by §213.127.

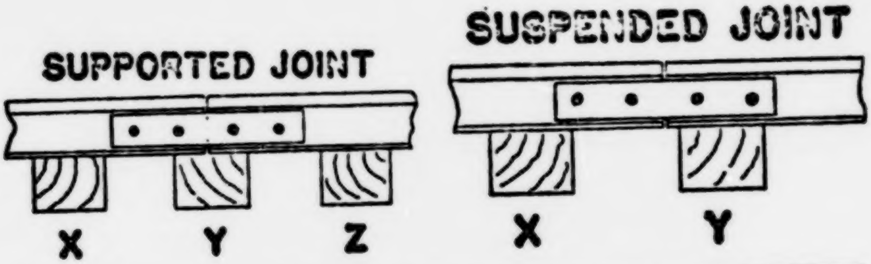
(c) If timber ties are used, the minimum number of nondefective ties under a rail joint and their relative positions under the joint are described in Table 7-4. The letters in the chart correspond to letters underneath the ties for each type of joint depicted.

§213.121 Rail joints

(b) If a joint bar on classes 3 through 6 track is cracked, broken, or because of wear allows vertical movement of either rail when all bolts are tight, it must be replaced.

TABLE 7-4

NONDEFECTIVE TIES CHART



Class of track	Minimum number of nondefective ties under a joint	Required position of nondefective ties	
		Supported joint	Suspended joint
1	1	X, Y, or Z	X or Y.
2, 3	1	Y	X or Y.
4, 5, 6	2	X and Y, or Y and Z.	X and Y.

Effect

These two sections require (1) increasingly firm tie support for joints with higher track classes and (2) the prevention of relative vertical motion of two rails at a joint. The effect of a poorly supported joint is to allow the rail to deflect more than usual under load. If the joint bar connecting abetting rails were extremely tight and well fitted, as is the case for classes 3 through 6 track, this deflection would not have serious noise consequences. However, the track standards allow for poor support at joints *and* relative vertical motion of the rails for class 1 and 2 track. Under these conditions, noise is expected to be significant.

Rail joints are one of the major sources of railroad track noise. They account for the familiar "clickety-clack" one hears as wheels pass over the joint. Accordingly, the noise from this type of mechanism is one of the important sources of community noise from rail lines. The noise level from impact at rail joints is proportional to 20 log V, where V is the train velocity.* Accordingly, a train traveling at 50 mph over class 2 track would generate approximately 6 dB more noise than if it were traveling at the legal limit of 25 mph.

§213.113 Defective rails

(b) If a rail in classes 3 through 6 track or class 2 track on which passenger trains operate evidences any of the conditions listed in Table 7-5, the remedial action prescribed in the table must be taken.

TABLE 7-5

REMEDIAL ACTIONS

Condition	If a Person Designated Under §213.7 Determines That Condition Requires Rail To Be Replaced	If a Person Designated Under §213.7 Determines That Condition Does Not Require Rail To Be Replaced
Shelly spots Head checks Engine burn (but not fracture) Mill defect	Limit speed to 20 mph and schedule the rail for replacement.	Inspect the rail for internal defects at intervals of not more than every 12 months.
Flaking Slivered Corrugated Corroded	Inspect the rail at intervals of not more than every 6 months.	Inspect the rail at intervals of not more than every 6 months.

(c) As used in this section.

(12) "Shelly spots" means a condition where a thin (usually three-eights inch in depth or less)

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*Source: Remington, Rudd, and Vér (1975).

shell-like piece of surface metal becomes separated from the parent metal in the railhead, generally at the gage corner. It may be evidenced by a black spot appearing on the railhead over the zone of separation or a piece of metal breaking out completely, leaving a shallow cavity in the railhead. In the case of a small shell, there may be no surface evidence, the existence of the shell being apparent only after the rail is broken or sectioned.

(13) "Head checks" mean hair-fine cracks which appear in the gage corner of the railhead, at any angle with the length of the rail. When not readily visible, the presence of the checks may often be detected by the raspy feeling of their sharp edges.

(14) "Flaking" means small shallow flakes of surface metal generally not more than one-quarter inch in length or width that break out of the gage corner of the railhead.

Effect

This sample of Sec. 213.113 illustrates that train speed is limited on defective rail, if an inspector decides the rail must be replaced. Defects such as shelly spots on the rail running surface will generate noise in much the same way as joints.

§213.115 Rail end mismatch

Any mismatch of rails at joints may not be more than that prescribed by Table 7-6.

TABLE 7-6

LIMITATIONS OF RAIL MISMATCH

Class of Track	Any Mismatch of Rails at Joints May Not Be More Than The Following	
	On the Tread of the Rail Ends (Inch)	On the Gage Side of the Rail Ends (Inch)
1	1/4	1/4
2	1/4	3/16
3	3/16	3/16
4,5	1/8	1/8
6	1/8	1/8

Effect

Noise from joints is a function of train speed, as mentioned above, and of mismatch in rail heights. Mismatch on the gage side of the rail ends is not expected to be significant but mismatch on the tread side of the rail ends (i.e., the running surface) is important. For this type of mismatch, noise increases as 10 log (h), where h is the amount of height difference.* Accordingly, at a given train speed, noise will be 3 dB more for track with 1/4-in. mismatch (Class 1,2) than for track with 1/8-in. mismatch (Class 4,5,6).

§213.117 Rail end batter

(a) Rail end batter is the depth of depression at one-half inch from the rail end. It is measured by placing an 18-inch straightedge on the tread on the rail end, without bridging the joint, and measuring the distance between the bottom of the straightedge and the top of the rail at one-half inch from the rail end.

---

*Source: Remington, Rudd, and Vér (1975).

(b) Rail end batter may not be more than that prescribed by Table 7-7.

TABLE 7-7

RAIL END BATTER LIMITATIONS

Class of Truck	Rail End Batter May Not Be More Than (Inch)
1	1/2
2	3/8
3	3/8
4	1/4
5	1/8
6	1/8

Effect

Qualitatively, rail end batter has much the same effect as joint mismatch. As illustrated in figure -1, even if the joint ends are aligned, the wheel leaves one rail and contacts the next at an angle which causes the wheel to be pushed suddenly upward and the rail down. The result is an impact noise, the level of which increases with increasing batter.

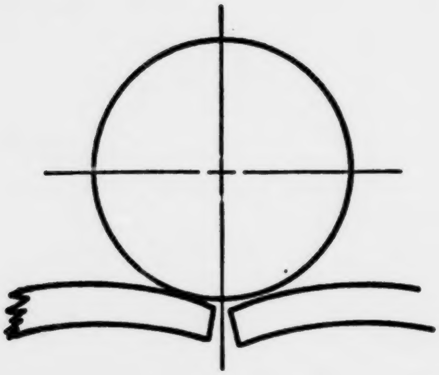

FIGURE 7-1. SCHEMATIC SHOWING MECHANISM OF RAIL-END BATTER.

§213.137 Frogs*

(c) If the tread portion of a frog casting is worn down more than three-eighths inch below the original contour, operating speed over that frong may not be more than 10 miles per hour.

Effect

As with rail end batter, degradation of frog tread increases noise.

Wheel Standards (Part 215)

Part 215 requires that each railroad freight car which has a component described as defective in this part must be (a) repaired or (b) removed from service (§215.7). Furthermore, "any railroad that operates a railroad freight car in violation of any requirement prescribed in this part is liable to a civil penalty of at least $250 but not more than $2500 for each violation. Each day of each violation constitutes a separate offense" (§215.19).

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*A "frog" is the X-shaped member that is used where one rail crosses another, as in a turn-out.

§215.43 Defective Wheels

A wheel is defective if it has any of the following conditions:

(g) Contiguous (adjoining) pieces of metal shelled out of the circumference of the tread.

(h) A slid-flat spot more than 2½ inches in length or two adjoining flat spots each more than 2 inches in length.

Effect

Wheel flats and shelled spots cause an impulsive noise each time the defective area contacts the rail. This noise can often be detected aurally as a "clunking" sound in a passing train. Furthermore, the noise level increases with increasing flat spot dimension. Accordingly, compliance with §215.43 will decrease community noise.

Appendix Q

RAIL CAR NOISE LEVEL DATA

Table 1. Example of Observed Rail Car Noise Level Variations Due to Sound Level Meter Detector Time Constant and Statistical Variations over Train Length for a Fifty-Car Freight Train Traveling at 34 MPH on Welded Rails (less locomotive noise).

	Actual Time (sec)	"Impulse" 35 ms (dBA)	"Fast" 125 ms (dBA)	"Slow" 1000 ms (dBA)
Computed Percentile L_{99}	50	75.5	75.5	76.0
" " L_{90}	45	77.0	77.0	77.5
" " L_{50}	25	79.0	79.0	79.0
" " L_{10}	5	81.0	81.0	80.5
" " L_{1}	.5	82.5	82.5	81.0
" " $L_{.1}$	.05	85.0	85.0	81.0
Maximum Level (dBA)	51	85.0	85.0	81.0
"Max." Meter Reading	51	85.0	84.0	81.0

Fig. 1. Maximum Rail Car Noise Level Measured at 100 feet by Wyle and DOT/TSC

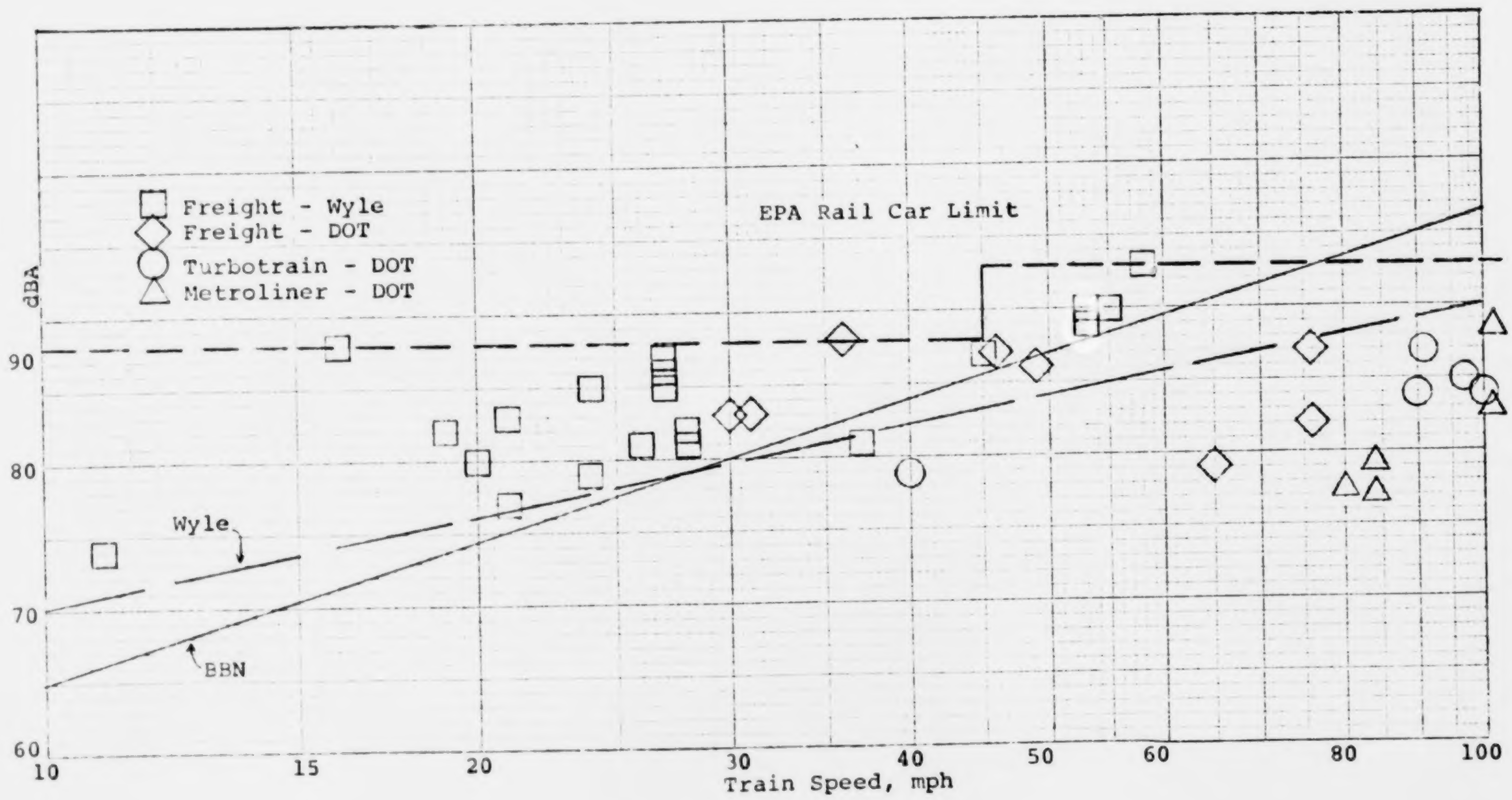


Fig. 2. Average Freight Rail Car Noise Level Measured at 100 feet by Wyle and BBN

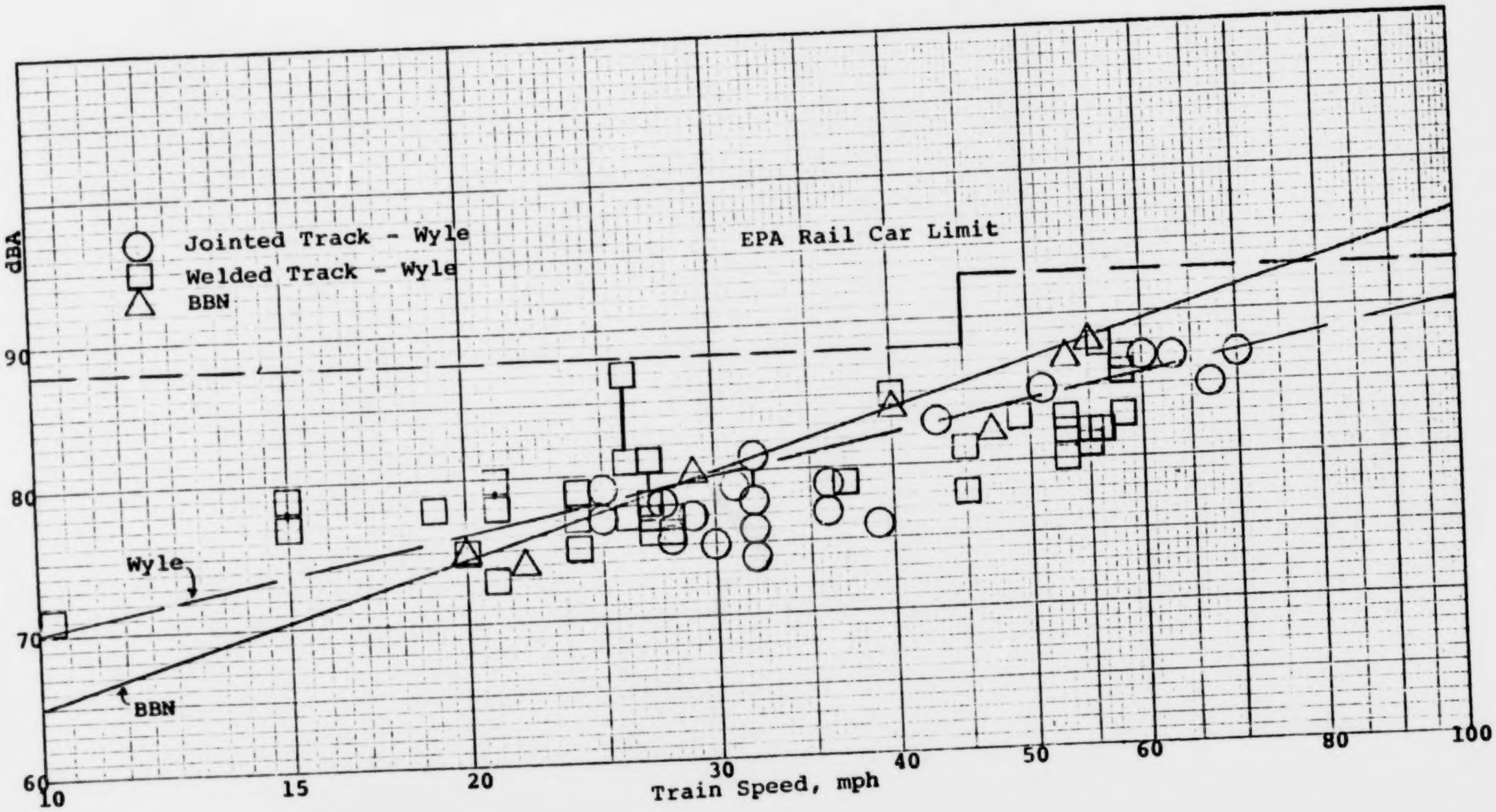


Fig. 3. Maximum and Average Rail Car Noise Level Measured at 100 feet by Kamperman Associates

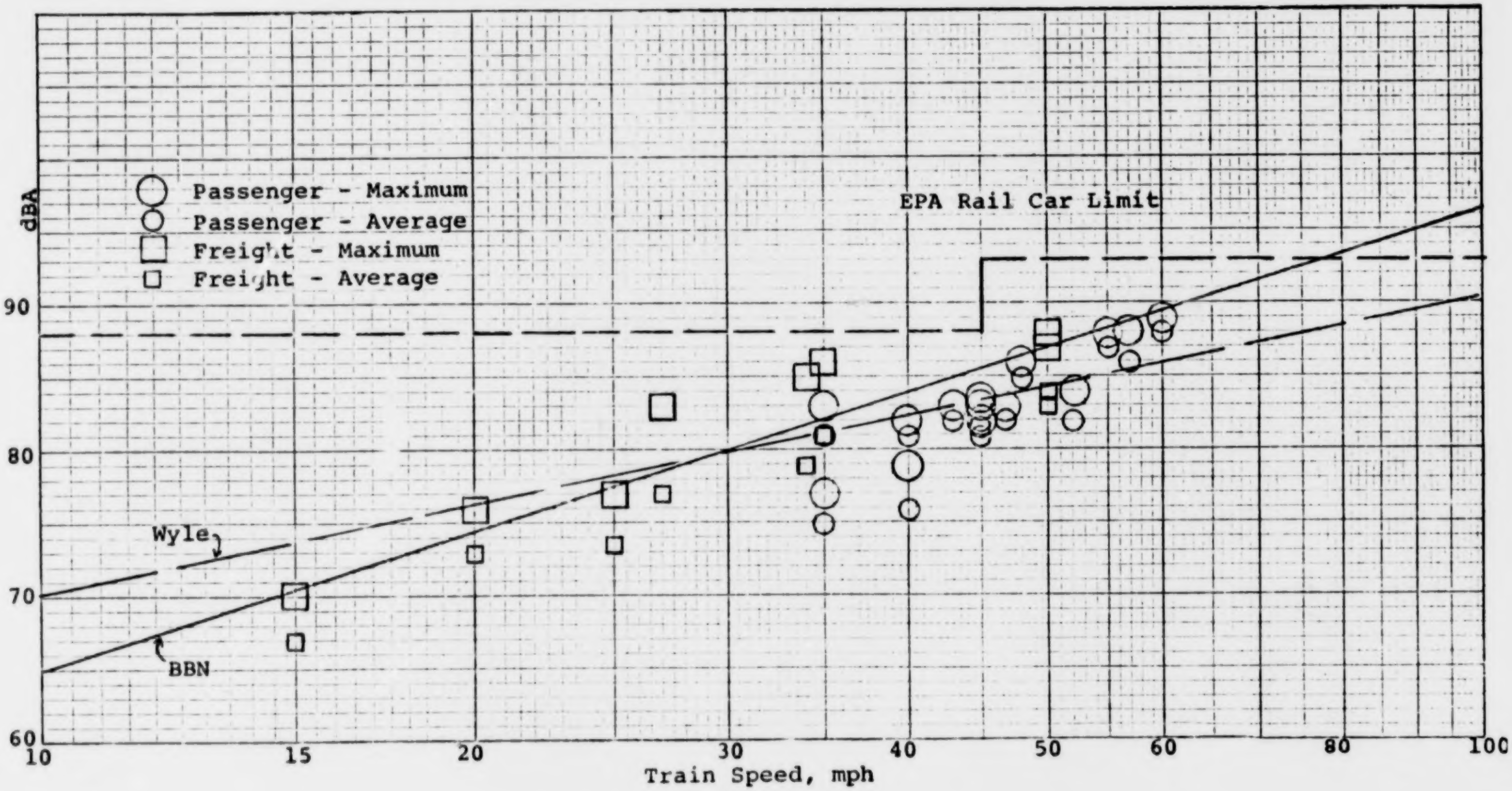
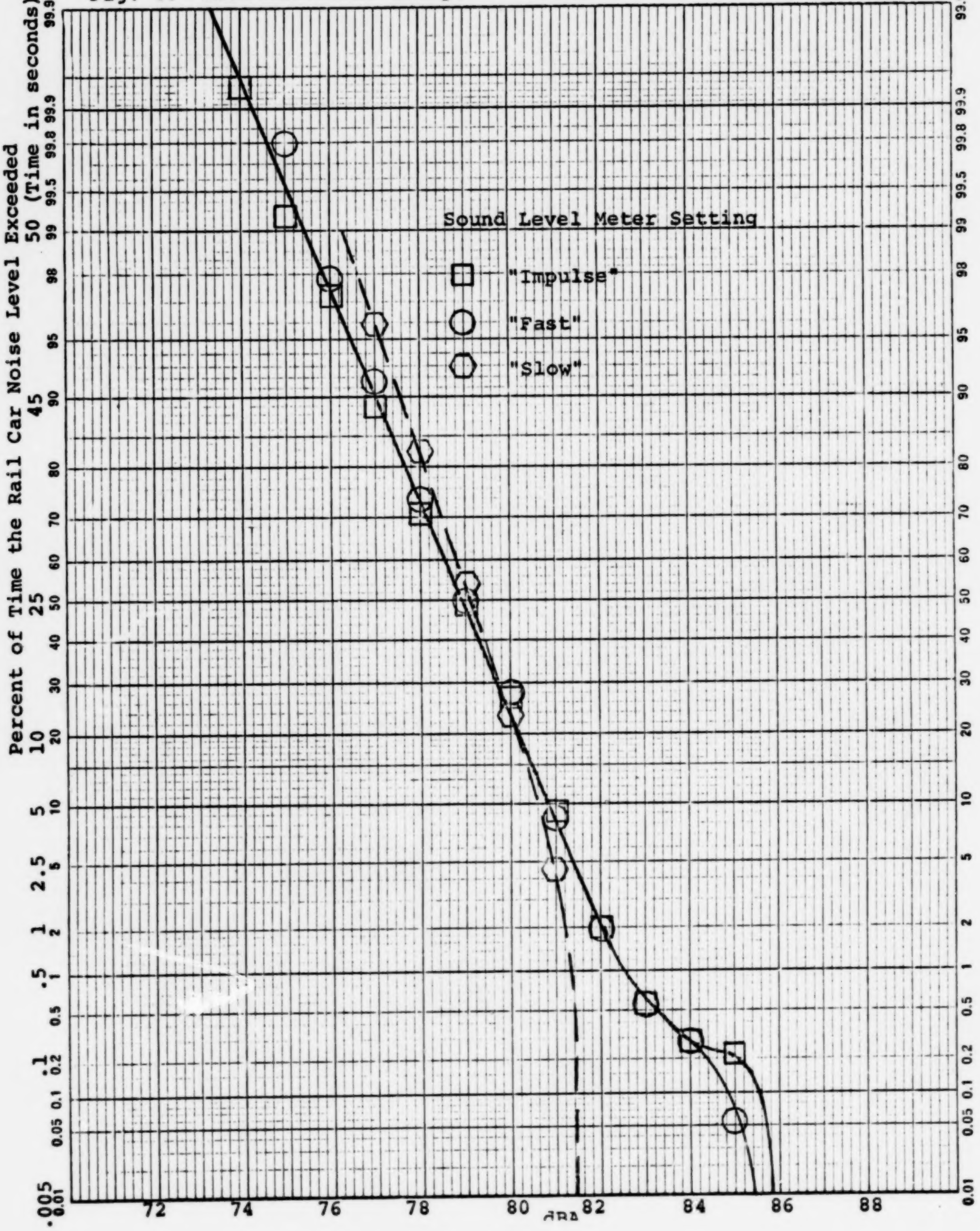


Fig. 4. Rail Car Noise Example in Table 1



Appendix R

ANALYSIS OF PUBLIC COMMENTS ON THE ENVIRONMENTAL PROTECTION AGENCY PROPOSED RAILROAD NOISE EMISSION STANDARDS

TABLE OF CONTENTS

Page

A. INTRODUCTION 1

B. COMMENTS DIRECTED TO SPECIFIC SECTIONS OF THE PROPOSED REGULATIONS 2

- Section 201.1 - Definitions 2
- Section 201.10 - Applicability 2
  - a. Warning Devices 4
  - b. Fixed Facilities/Retarders 8
  - c. Special Purpose Equipment 13
  - d. Track and Right of Way 15
  - e. Refrigerator Cars/Auxiliary Engines 16
- Section 201.11 - Standards for Locomotive Operation Under Stationary Conditions 20
  - a. Locomotive at Idle 20
  - b. Locomotive at any Throttle Setting Except Idle 24
- Section 201.12 - Standard for Locomotive Operation Under Moving Conditions 26
- Section 201.13 - Standard for Rail Car Operations 27
- Sections 201.11, .12, .13 - 270 Day Standard 28

C. COMMENT ON ADDITIONAL ISSUES 29

- 1. Meeting the Standard with Newly Manufactured Locomotives 29

TABLE OF CONTENTS (Cont'd)

Page

2. Meeting the Standards with Existing Locomotives (Retrofit) 29
   a. Economic Considerations 29
      (1) Economic Impact in General 29
      (2) Economic Impact on Bankrupt/Marginal Railroads 35
   b. Technical Considerations 36
3. Health and Welfare 40
4. Legal Considerations 42
5. Measurement Methodology and Compliance Regulations 45
6. Special Local Conditions 48
7. Property Line Standards 50
8. Background Document Data and Information 51
9. Statements of Support 53

D. SYNOPSIS OF COMMENTS FROM THE SPECIAL CONSULTATION MEETING ON THE PROPOSED INTERSTATE RAILROAD NOISE EMISSION STANDARDS 54

INDEX OF WRITTEN DOCKET SUBMISSIONS i

INDEX OF SPECIAL CONSULTATION MEETING PARTICIPANTS iii

A. INTRODUCTION

On July 3, 1974, a Notice of Proposed Rulemaking on the Interstate Rail Carrier Noise Emission Regulations was published in the Federal Register. In the same publication, notice was also given of the availability of the Background Document and Environmental Explanation for the Proposed Interstate Rail Carrier Noise Emission Regulations. Public comment was solicited with respect to both the proposed regulations and the data presented in the Background Document, with the period extending from July 3, 1974, to August 17, 1974. On August 14, 1974, a special consultation meeting was held on the proposed regulations.

The public comments received relative to the proposed regulation and the Background Document as well as the transcript of the special consultation meeting make up the total body of public comment received.

The contents of all docket submissions have been reviewed and analyzed by the staff of the Environmental Protection Agency. These analyses follow.

A synopsis of the issues raised in the transcript of the special consultation meeting has been included as a separate section of this document. All of the issues raised in that meeting have been addressed in the analyses which precedes such synopsis.

All public comment associated with this regulation is maintained at the EPA Headquarters, 401 M. Street, S.W., Washington, D.C. 20460, and are available for public inspection during normal working hours (Monday through Friday, 8 am to 4:30 pm).

B. COMMENTS DIRECTED TO SPECIFIC SECTIONS OF THE PROPOSED REGULATIONS

Section 201.1 - Definitions:

The New York Department of Environmental Conservation and the Department of Transportation both indicated that since the term "retarder" is not used in the regulation its definition should be eliminated from Section 201.1. In addition the DOT raised the same point concerning the term "sound pressure level."

Both definitions have been removed from Section 201.1.

Section 201.10 - Applicability:

There were a considerable number of different questions and issues received which dealt with the applicability of the regulation to various types of railroad facilities and equipment. The Association of American Railroads raised questions of a largely legal nature dealing with matters involving the interpretation of the Act and with the EPA's duties and authority. The Agency has addressed these legal questions in a later section of this analysis. Other questions dealt with matters peculiar to the particular railroad facilities or equipment at issue, and are discussed in detail below. However, a significant number of comments, in particular those of the Association of American Railroads, US Department of Transportation, Illinois Railroad Association, and the Fruit Growers Express Company, also brought into issue the general question of why the EPA decided, apart from considerations of available technology and cost of compliance, not to regulate all railroad facilities and equipment, and chose rather to regulate only certain equipment at this time.

This decision by the EPA was based on its view that the uniform Federal regulation of the noise produced by certain railroad facilities and equipment is not necessary at this time since such noise sources can best be controlled by measures which do not now require national uniformity of treatment in order to facilitate interstate commerce as specified in Section 2(a)(3) of the Act.

The EPA has studied the operations of the rail carriers engaged in interstate commerce by rail and has seen that such operations are imbedded into every corner of the nation at thousands of locations and along hundreds of thousands of miles of right-of-way. The nature and magnitude of the noises produced by the many types of facilities and equipment utilized in these operations differ greatly and their impact on the environment varies widely depending on whether they occur, for example, in a desert or adjacent to a residential area. The Agency concludes that the control of certain of these noise sources, such as fixed facilities, or equipment used infrequently or primarily in one location, is best handled by the State and local authorities, rather than the Federal government. State and local authorities are believed in this case to be better able than the Federal government to consider local circumstances in applying such measures as the addition of noise barriers or sound insulation to particular facilities, or the positioning of noisy equipment within these facilities as far as possible from noise-sensitive areas. Further, and more importantly, the EPA did not find during its analysis, and has not received from rail carriers, any information identifying situations where the lack of uniform State and local laws with respect to these facilities and equipment has imposed any significant burden on interstate commerce.

In view therefore of the absence of evidence calling for the national regulation of all railroad facilities and equipment in order to facilitate interstate commerce, the EPA believes that its limited regulatory action as proposed in the Notice of Proposed Rule Making to consider railroad operations, facilities, and equipment on an individual basis in deciding the need for their uniform Federal regulation is appropriate.

a. Horns, bells, whistles, and other acoustic warning devices.

The New York Department of Environmental Conservation, the South Carolina Department of Health and Environmental Control, and the Oregon Department of Environmental Quality, all indicated that complaints from citizens about railroad warning device noise were not only large in number but comprised the major source of all complaints about railroad noise, and therefore contended that such warning devices should be regulated.

The Agency in analyzing the problem of acoustic warning device noise recognized a unique characteristic of such noise as opposed to other railroad noises. That is, it is a form of noise that is purposefully created and intended to be heard for safety reasons, instead of being an unwanted by-product of some other activity. As such, the EPA found that these warning devices and their use are regulated at both the Federal and State levels. Federal regulations ensure that such devices on locomotives are suitably located and in good working order, (Safety Appliance Act, 45 USCA; 49 CFR, 121, 234, 428, 429). State regulations are oriented toward specifying the conditions of use of these devices. A recent study of the 48 contiguous States (see Appendix B of Background Document) shows that 43 of these States have such regulations. In addition, studies considered by the EPA also included in Appendix B of the Background Document show that such warning devices do not appear to be unrelated to highway and pedestrian safety, especially in emergency situations. The reduction or elimination of such warning devices through the authority of the Noise Control Act does not therefore appear to be a reasonable consideration as suggested by B. Leath, the South Carolina Department of Health and Environmental Control, and Citizens Against Noise.

The EPA does recognize that a noise problem exists as to the use and extent of railroad warning devices, and that regulatory action may be appropriate for controlling same. However, the Agency believes that the requisite regulation can best be considered and implemented by State and local authorities who are better able to evaluate the particular local circumstances with respect to the nature and extent of the noise problem and the requisite safety considerations involved. Any comprehensive Federal regulation in this area could be overly diverse and cumbersome. The EPA encourages in this regard the interaction between local and State governments and the railroads directly concerned in solving the particular local noise problems associated with the use of such warning devices. Such interaction has taken place, examples of which are included in the Background Document, and has apparently produced both safe and cost effective solutions to these local noise problems. However, if local authorities, after having first sought solutions with the railroads involved, have still not been able to resolve their problems, they are encouraged to then direct their concerns to the EPA for possible further Federal action.

The South Carolina Department of Health and Environmental Control and the Oregon Department of Environmental Quality expressed the opinions that acoustic warning devices are not needed around railroad yards, and are overused by the railroads, respectively.

The EPA has determined that the use of such warning devices in and around railroad yards is not entirely out of place due to the often heavy intermingling of workers and mobile equipment with locomotives and rail cars. Such use may of course be beyond the extent necessary to ensure safety, not only in railroad yards but wherever else railroad horns, bells, and whistles are used. The term "overused" however, is relative to the particular circumstances surrounding such use: whether, for example, a railroad yard or rail-highway intersection is situated in a residential as opposed to an industrialized area. These situations are instances where the EPA's recommendation for railroad and community interaction is at this time the most appropriate means of achieving effective warning device noise abatement.

R. Leath stated that railroad acoustic warning signals are ineffective due to the often loud ambient noise levels that exist in motor vehicle interiors due to radios and other noise sources.

Acoustical analysis available to the Agency indicates that the effectiveness of acoustic warning signals as used on police and emergency vehicles as well as urban buses and trucks is a function of frequency or tonal characteristics as well as amplitude or loudness. That is, recognition is achieved by a particular fixed or variable frequency of a reasonable loudness that impinges itself upon whatever ambient noise may exist. This view is in accord with the study referenced above which indicates that railroad warning signals do not appear to be unrelated to safety, especially in emergency situations.

R. Leath also indicated that roadway drop gates equipped with flasher units provide visual warning that is adequate without acoustic signals.

EPA encourages alternate solutions to the routine use of acoustic warning devices at rail and road crossings. For example, the elimination of public grade level railroad crossings would do away with the source of the problem, the intersection of rail tracks and public thoroughfares. Such a program on a national basis of elevating or depressing either the railroad line or the public thoroughfare at each crossing, solely for the purpose of the abatement of acoustic warning signal noise, is not considered appropriate. However, it should be seriously considered in future public thoroughfare or railroad line construction programs for both safety and environmental noise reasons.

Warning gates too, as suggested, would appear to be an effective safety alternative to acoustic warning signals. Specifying their use on a national basis, however, would be prohibitively expensive considering that costs range from $45,000 to $90,000 per unit, and that with the extensive use of grade level crossings in the United States, for example Illinois having 15,000 railroad crossings without drop gates, the cost would be $675 million or more in that State alone.

b. Repair and maintenance shops, terminals, marshaling yards, humping yards, and specifically, railcar retarders.

The Association of American Railroads commented that the EPA should prescribe noise standards for area-type sources such as yards and terminals.

The facilities and equipment found within railroad yard and terminal areas, with the exception of locomotives, rail cars, and some mobile special purpose equipment, are permanent installations which are normally subject to the environmental noise regulations of only one jurisdiction.

The Agency has determined that such fixed facility railroad yard and terminal noise is best controlled at this time at the local level, employing measures which do not in themselves affect the movement of trains and therefore do not require national uniformity of treatment. Significantly, the Agency has received no indication that existing State or local ordinances which regulate noise emissions from such fixed facilities, have in fact created any substantial burden on interstate commerce.

Local jurisdictions are familiar with the particular complexities of their their community/railroad yard noise situation, and as such, are in a position to exhibit greater sensitivity in prescribing practical and cost effective solutions to the local noise problem. Indeed, although the AAR has encouraged the establishment of Federal area noise standards for yards and terminals, it specifically pointed out in its remarks that such facilities do vary in size, shape, and special characteristics, and that the noises produced there are diverse. The EPA recognizes that the communities which neighbor these yards and terminals are equally diverse, varying in land zoning and population density and distribution. As such, a Federal regulation which successfully produces substantial population health and welfare benefit at one locality may produce little or no such benefit at another locality. For example, the regulation of a railroad yard facility which is enveloped by a residential community would not achieve similar population health and welfare benefit when equally applied to a similar railroad yard facility which exists within a large industrial park complex. This observed differential is directly attributable to the different land zoning and population density and distribution characteristics of the two communities.

Acknowledging both the single jurisdictional nature and the diversity which characterize railroad yards and terminals and their neighboring communities, and citing the virtual absence of evidence that nonuniform State and local regulation of railroad yard and terminal facilities in fact substantially burdens interstate commerce, the Agency at this time does not propose to establish standards for the regulation of railroad yard and terminal fixed facility noise.

The Department of Transportation commented that the EPA should regulate retarder noise emissions. They indicated that active retarders should be regulated by October 1976 since established barrier technology makes it possible to meet that schedule. DOT further stated that a plan to convert to retractable inert retarders should be implemented by 1979.

The EPA recognizes that rail car retarding operations may produce individual peak noise levels of up to 120 dB(A) at 100 feet, and may be a problem noise source to the surrounding community. However, as with other fixed facilities, retarders are subject to only one jurisdiction, and as such can best be regulated at the local level by means which do not in themselves affect the movement of trains and therefore do not require national uniformity of treatment.

The Agency's study of railroad yard noise (inclusive of retarder noise) indicates that concern for noise from railroad yards is apparently limited to certain locales, and is not a national concern. This is due in large part to the location of a number of yards in non-urban areas and the relatively few existing retarder systems, approximately 120 today. This local nature of the retarder noise problem further reduces the desirability of a Federally preemptive regulation.

DOT's comment in support of a Federally preemptive retarder noise regulation which would utilize barrier technology does not consider the local characteristics of each community which is impacted by retarder noise. For example, in a situation where a retarder yard is bordered on one side by a residential area and on all other sides by an unpopulated wooded area, a barrier could be beneficial to public health and welfare on that side of the retarder which faces the residential area. Under such circumstances a community would receive insufficient health and welfare benefits to justify the costs incurred by a Federally preemptive regulation which mandates the installation of barrier walls on both sides of retarders. At the currently estimated materials cost of $70 to $100 per linear foot for barriers, barrier costs would run from $50 thousand to $100 thousand per railroad yard and from $9.6 to $19.1 million for the entire railroad industry. Maintenance and replacement costs, yard down time, and track modification costs have not been fully identified. Expenditures should be assured of producing maximum benefits, and this may best be done through local regulation. Available space for installation of barriers, and safety hazards, which might accrue thereto, have not been identified, and are peculiar to the particular characteristics of the individual railroad yards, and as such may be best accounted for through local regulation.

A Federal regulation for conversion of inert retarders to retractable inert retarders would be subject to considerations similar to those discussed for the erection of barriers around active retarders, except that probable yard down time and installation and materials costs would be considerably greater for conversion to inert retractable retarders than for the erection of barriers. The EPA estimates that conversion to retractable inert retarders would cost $7.5 thousand for each retarder, not including labor, yard down time, or maintenance costs.

Applying a gross estimate of 20 thousand such retarders nationally, estimated national conversion costs to the retractable mode, exclusive of labor, yard down time, and operational costs, would be $150 million.

Although the EPA does not currently propose to regulate retarder noise, it does recommend that local jurisdictions establish regulations which require railroads to utilize barrier technology where needed, and where both practical and feasible. Further consideration may be given by the EPA to possibly providing future regulations to require that new retarder installations be equipped with retractable inert retarders, computer control systems, retarder beam lubrication systems, or other available technical developments which result in significant noise reduction from retarders as the need for such regulations is demonstrated relative to the costs involved and the availability of of technology.

DOT also commented that the EPA should promulgate a regulation which protects railroad workmen as well as the community from retarder noise.

For reasons outlined above, the EPA does not presently propose to regulate retarder noise from either the community health and welfare or the occupational health and safety point of view. The latter consideration is specifically under the purview of the Occupational Safety and Health Administration (OSHA) and is properly addressed by that Agency.

Currently, the Federal Railroad Administration (FRA) is proposing a regulation which would limit noise levels within railroad workmen's sleeping quarters. This proposal is in response to a petition from the Congress of Railway Unions (CRU) that the FRA institute rulemaking procedures to prohibit railroads from having or providing employee sleeping quarters less than one mile from its property or yards where switching or humping operations are performed. The FRA's proposed regulation does not regulate the distance of sleeping quarters from the railroad yard; however, it does specify acceptable interior noise levels for sleeping quarters.

c. Special purpose equipment.

The Association of American Railroads commented that the EPA should promptly establish noise limits applicable to the noise from special purpose equipment.

Examples of special purpose equipment which may be located on or operated from rail cars include: ballast cribbing machines, ballast regulators, conditioners and scarifiers, bolt machines, brush cutters, compactors, concrete mixers, cranes and derricks, earth boring machines, electric welding machines, grinders, grouters, pile drivers, rail heaters, rail layers, sandblasters, snow plows, spike drivers, sprayers and other numerous types of maintenance-of-way equipment.

The Agency realizes that special purpose equipment such as that used for maintenance-of-way activities is essentially construction equipment, and as such may emit loud intermittent noise. Railroads may avoid noise problems by keeping routine maintenance activities to reasonable times, and local jurisdictions may easily regulate operation times for such equipment as long as exceptions are allowed for emergency use. For example, a community may wish to regulate the hours allowed for routine operation of spike driving equipment, but exception must be made for the operation of such equipment in the aftermath of a derailment, so that interstate commerce would not be unduly impeded.

The small numbers of such equipment, their infrequency of use, and the relative ease with which viable local regulations may be instituted, all tend to make a Federally preemptive regulation overly expensive relative to the benefits received.

Comments received by the Agency did not indicate that any cases currently exist where nonuniform local or State regulation of special purpose equipment has unduly burdened those railroads so regulated, and at this time the Agency does not believe that special purpose equipment requires national uniformity of treatment. However, the rail cars themselves on which such special purpose equipment is located are included under the standards for rail car operations. The Agency continues to solicit notice of specific cases where nonuniform local or State regulation of special purpose equipment has created a burden on interstate commerce. If in the future it appears that national uniformity of treatment of such equipment is appropriate, noise emission standards may be proposed.

d. Track and Right of Way.

The Minnesota Pollution Control Agency, the Illinois Environmental Protection Agency, and the ADM Company raised questions dealing with the absence of track and right-of-way standards in the proposed regulation. The Minnesota Pollution Control Agency and the Illinois Environmental Protection Agency stated that in view of the fact that the EPA had preempted State and local authorities from regulating track and right-of-way in the Notice of Proposed Rule Making, it was in conflict with its mandate to issue noise emission standards reflecting "best available technology" since the regulation itself did not contain any track standard. The ADM Company was concerned that since a track standard was not included in the regulation, quiet railcars might be penalized for wheel/rail noise caused by faulty track.

The EPA fully recognizes the need for track and right-of-way standards in any regulatory strategy that attempts to quiet the movement of rail cars.

The standard promulgated for rail cars applies to the total noise produced by the operation of trains on tracks. As such it is preemptive with respect to both rail cars and track. It reflects the noise level achievable by application of best maintenance standards to rail cars. Further reductions in noise levels are achievable through various track repairs and modifications. However, the EPA has not fully identified the available technology or the applicable costs associated with such practices. In the future, the EPA may propose standards which would require their application.

e. Rail cars equipped with auxiliary power equipment, and mass transit systems.

The Department of Transportation and Fruit Growers Express Co. recommended the inclusion of noise standards for mechanically powered refrigerator cars in the regulation. In addition, the National Railroad Passenger Corporation (AMTRAK) called for separate regulations dealing with passenger related cars equipped with auxiliary power equipment.

The initial decision by the Agency was to regulate noise from all sources produced by rail cars while in motion only, and to leave to State and local authorities the regulation of whatever noise is produced from rail cars while stationary. This decision was made because these noises are a problem only when such cars are parked near noise sensitive areas (such noises being indistinguishable from other railroad car noises while the cars are in motion), and because it was felt that such localized problems could best be controlled by measures such as the relocation of such cars to less noise-sensitive areas.

The Agency was and continues to be cognizant of the extent of the problem that can be caused in specific instances by the continuous operation of the diesel or gasoline engines which operate on such cars. Noise levels as high as 75 dB(A) at 15 meters (50 feet) are possible from refrigerator cars parked with their cooling systems running in marshalling yards and humping yards. Noise from refrigeration cars becomes a more appreciable problem due to the fact that operating refrigerator cars are often parked coupled together in large numbers.

Additional data acquired by and supplied to the Agency has shown that the problem exists not only with refrigerator cars but also with various passenger-related cars such as dining cars, lounge cars, cafe-type cars, and others equipped with self contained power units; and that the abatement of such noise appears able to be and in certain instances is now being accomplished through the use of existing muffler designs. In this regard, and in response to the point raised by Fruit Growers Express Co., the statements on p. 4-28 and 4-37 of the original Background Document have been corrected to reflect the use (although of undetermined adequacy) of mufflers on the auxiliary engines used in refrigerator cars.

The Agency therefore may consider the possible promulgation of a regulation dealing with the noise produced by mechanically refrigerated freight cars and passenger cars equipped with auxiliary power equipment so as to reduce the impact of such noise when these cars are parked near noise sensitive areas.

It should be noted that in the regulation being promulgated herein, the standard for rail car operations refers to the total noise generated, and that the setting of emission standards on any element of that noise is preempted, whether the rail car is in motion or stationary. This Federal regulatory action does not, however, interfere with the ability of State and local governments to enact or enforce noise emission regulations on railroad yards that require railroads to erect noise barriers. Nor does this regulation interfere with the ability of State and local governments to enact or enforce noise emission regulations which require the relocation of parked rail cars that generate noise so long as such regulation is reviewed and approved by EPA pursuant to Section 17(c)(2) of the Act.

Fruit Growers Express Co. asked for an extension of the period of time prior to promulgation of the final regulation so that refrigerator car noise emissions could be studied in relation to wheel/rail noise.

Studies and data considered by the EPA show that such noise can range from 72 dB(A) (Thermo King Corporation, a major manufacturer of refrigeration equipment, 1975) to 75 dB(A) (Wyle Laboratories, an acoustical consulting firm, 1973), and that it is indistinguishable from overall train noise while the train is moving. As such, and in the absence of a showing that the existing data is questionable, no extension has been granted.

The Department of Transportation expressed concern for the fact that very few refrigerator cars are owned by the railroads, and that, consequently, refrigerator car owners' ability to pay for mufflers should be considered quite apart from the economic position of the railroads.

As indicated above, this regulation does not require the abatement of refrigerator car auxiliary equipment noise, and accordingly there is no related cost of compliance incurred. Consideration as to the costs to be incurred by the actual owners of such rail cars as may be affected by any future regulatory action would be fully and adequately addressed during the course of the regulatory process that would be conducted relative to such regulation.

Citizens Against Noise suggested that the regulation be made applicable to the operation of and equipment utilized by intraurban mass transit systems.

The Agency has not intended and does not intend that intraurban mass transit systems be covered by the regulation being promulgated herein. It is the Agency's judgment that such systems are specifically excluded from regulation under Section 17 of the Noise Control Act of 1972 by the definition of "carrier" cited in the Act which excludes "... street, suburban, and interurban electric railways unless operated as a part of a general railroad system of transportation." In addition such systems operate principally within one jurisdiction or in some cases throughout a small number of contiguous metropolitan jurisdictions under the purview of a single transit authority, and as such do not appear to require uniform Federal regulation in order to facilitate interstate commerce. However, the exclusion of such systems does not also exclude the operations and equipment associated with commuter rail services provided by a number of interstate rail carriers.

Section 201.11 - Standards for Locomotive Operations Under Stationary Conditions.

a. Locomotive at Idle

Both General Motors and the AAR commented on the proposed idle standard. While the AAR comment was general and they stated only that a muffler that meets the proposed full throttle standard is not likely to meet the idle requirement too, General Motors' comment was quite specific and was backed by data. Within the text of the General Motors document entitled "Additional Comments of General Motors Corporation With Respect to the Proposed Railroad Noise Emission Standards," General Motors offers a graphical analysis of idle noise level emissions as measured for SD40-2, GP39-2, and GP38-2 locomotives. The graphs compare A-weighted octave band sound levels measured at three feet from the exhaust outlet and 100 feet from the side of the locomotive during full power. Radiator cooling fans were not operating during the time of the testing in order to eliminate their influence. Quoting General Motors:

> Inspection of these plots shows that a good correlation for all three locomotives can be made between the full power exhaust noise inspection at three feet and the overall locomotive noise inspection measured at 100 feet, when a 30 dB attenuation factor for hemispherical sound spreading is used to correct for the increased distance. For most points, the measured octave band level at 100 feet, is less than that predicted using the 30 dB attenuation factor indicating excess attenuation not accounted for. When the measured octave band level is greater than that predicted, structurally radiated locomotive noise is contributing to the overall locomotive noise.

In the General Motors document entitled "Comment of General Motors Corporation with Respect to Proposed Railroad Noise Emission Standards," General Motors states "that our tests have shown that a muffler capable of reducing number 8 throttle position, full power locomotive noise by 5 dB (A) at 30 meters, reduces the idle locomotive noise only 0.5 dB(A) at 30 meters." This statement is not backed with specific data as was the case in General Motors Additional Comments.

Based on the above, General Motors summarized that a standard of 67 dB(A) at 30 meters during idle is not considered feasible by muffler technology alone, that engine exhaust is not the dominant source mechanism when the locomotive is in idle, and that structurally radiated sounds are dominant:

> It is GM's opinion that extensive car body treatment such as the addition of sound absorbing and damping materials, the addition of access door seals, the replacement of access doors and panels with acoustical shielding, or any combination of these methods, would be necessary in an attempt to achieve a standard 67 dB(A) at 30 meters under idle conditions. Such car body treatment violates the basic design concept of the narrow multi-door hood-type locomotive which number approximately 90% of the locomotives in use, in that it would greatly restrict the ease of maintenance and compliance.

GM estimated that car body modification alone would cost as much or more than a muffler retrofit program.

The General Motors data indicates that certain idling locomotives emit noise levels dominated by structural radiation which may be as high as 69 dB(A) at 100 feet. EPA data further indicates that some locomotives may emit idle noise levels in excess of 69 dB(A) which are also dominated by structurally radiated noise. Locomotives with such high levels of structurally radiated noise cannot be brought into compliance with the proposed level of 67 dB(A) through, for example, muffler application alone. Accordingly, the Agency has amended the locomotive idle noise standard, increasing the allowable noise emission level from the proposed 67 dB(A) to 70 dB(A) at 100 feet.

The National Railroad Passenger Corporation (AMTRAK) commented that diesel electric locomotives equipped with auxiliary power generators or twin traction engines, and gas turbine locomotives, may not be able to meet the idle standard, and that special standards should be promulgated for such equipment.

In proposing this regulation the Agency intended to provide Federal preemption for all locomotive noise sources excepting acoustical warning devices, thus providing national uniformity of treatment for these mobile noise sources. Accordingly, State and local regulation of noise emissions from such locomotives equipped with auxiliary generators used to power electrical units on passenger cars, including the noise from such auxiliary generators per se, should be Federally preempted.

Thus the Agency has determined that Federally preemptive regulation of noise from auxiliary power units is appropriate. However, the noise from such sources was not specifically addressed by the Agency during rule making, and the standard as proposed considered only idle setting noise emissions from the primary propulsion engines of the stationary locomotives.

Because passenger locomotives do spend considerable time in a stationary disposition with auxiliary power units operating at the same time that the primary diesel engines are idling, the Agency forsees circumstances where the auxiliary unit noise may dominate other noise emissions from the idling locomotive, and thus be appropriate for regulatory action. After further consideration of this matter the Agency may address noise standards for such auxiliary units in a separate rule making. However, because the intent of the Act was to provide national uniformity of treatment where non-uniform State and local ordinance could likely impose a burden on interstate commerce, and because the locomotive as a whole is subect to this regulation, the Agency believes that its regulatory action relative to locomotive noise emissions is also preemptive with respect to State and local ordinances relative to noise emissions from the auxiliary power units which are an integral part of many such locomotives.

The Agency has received no data which would indicate that twin-engined diesel-electric locomotives are in fact incapable of compliance with the idle standard. Since the Agency has no data which would demonstrate that twin diesel engines are inherently louder than larger single diesel engines, and since twin engined locomotives utilize the same basic diesel-electric technology as the more common single engined locomotives, separate standards for twin-engined diesel-electric locomotives are not included in this regulation. The standards as promulgated are therefore applicable to these locomotives.

While the Agency has sufficient data to confidently assess the ability of gas turbine-powered locomotives to meet the moving condition standard, the Agency has not been able to acquire sufficient data on the idle setting or stationary runup noise levels of gas turbine locomotives. Due to the virtual unavailability of such stationary noise data, the regulation as proposed has been revised, and the idle setting and stationary runup noise standards are no longer applicable to gas turbine locomotives. However, this regulation is preemptive with respect to State and local regulation of all turbine locomotive noise, excepting that from acoustical warning devices, including regulation when such locomotives are stationary at idle. After the Agency has compiled a sufficient data base, idle settings and stationary runup noise standards for gas turbine locomotives may be established as a revision to these regulations.

b. Locomotive at any Throttle Setting Except Idle.

The U.S. Department of Transportation (DOT) questioned the acoustical acceptability of the typical load cell test sites and the validity of self loading due to the unaccounted for influence of noise emissions from the dynamic brake grid fans. Also cited was the possible obstruction of routine railroad operations due to local enforcement of the stationary standards.

DOT indicated that areas near railroad load cells are not far enough from reflective surfaces to be effective test sites. They also indicated that if load cells are to be used for enforcement, the EPA should prescribe correction factors to account for the acoustical variability of actual load cell test sites.

In answering the above claim that load cells are unsuitable for locomotive noise measurement because they are situated too close to reflective areas, the EPA cites the fact that a number of load cells are portable and are readily available on a rental basis. These portable cells may be transported to an acoustically acceptable site for locomotive noise testing. At such sites, accurate and meaningful noise measurements may be obtained without the use of site correction factors.

Additional DOT response indicated that the self loading test is not valid because the cooling fans on the dynamic brake grids operate during self-loading, while in actual operations, grid fans are never operated. They state that the inherently high level of noise attributable to cooling fan operation (both engine and dynamic brake grid fans) during self load would interfere with the accurate and meaningful measurement of exhaust noise.

The EPA has considered the above comment and believes that objections to the self loading test are valid. Therefore, considering the difficulties involved in obtaining accurate measurements due to the interference of dynamic brake grid fan noise, and citing the availability of portable rented load cells, the Agency has decided to delete the self loading test as a recommended stationary testing procedure, while simultaneously endorsing the use of portable load cells.

DOT indicated concern that enforcement of stationary standards could result in significant obstruction of routine railroad operation and hence interfere with the flow of interstate commerce. That is, any enforcement official could order any one or any number of locomotives to be moved to a load cell or self load area for testing, regardless of the maintenance work schedule at the load cell or the need for the subject locomotives to be engaged in interstate commerce.

Such potential difficulties have been considered by EPA, and the Agency believes that their effects may be minimized through proper structuring of the DOT compliance regulations which may specify responsible enforcement procedures.

Section 201.12 - Standard for Locomotive Operation Under Moving Conditions:

The U.S. Department of Transportation (DOT) favors a moving locomotive standard as a substitute for a stationary standard, but stated that EPA's definition of wayside surface conditions should be improved.

The EPA strongly believes that a stationary as well as a moving locomotive standard is necessary in order to account for the varying nature of locomotive noise. Utilization of both stationary and moving standards also facilitates adequate and accurate enforcement. The additional measurement criteria which are being incorporated by the EPA as part of the final regulation will specify wayside surface conditions in greater detail.

The National Railroad Passenger Corporation (AMTRAK) indicated that the moving locomotive standard should be speed related as is the case with the rail car standard. They further stated that gear noise, traction motor noise, and noise from locomotive appurtenances are speed related.

EPA data indicates that while diesel-electric locomotive noise does not appear to be speed related, electric freight, electric high speed passenger, and turbine high speed passenger noise levels do exhibit some speed-related correlations. However, the high speed noise emission levels exhibited by these locomotives appear to fall within the EPA's 90 dB(A) standard, and should pose no special compliance problem.

Section 201.13 - Standard for Rail Car Operations:

DOT indicated that it is appropriate to limit any car regulation to at least two degree or wider turns as with the locomotive standard.

The EPA concurs with that statement and has made the appropriate changes in the Rail Car Standard.

A private car owner, the ADM Company, was concerned that the EPA Rail Car Noise Standards would require greater maintenance than that prescribed by the FRA (1974) Railroad Freight Car Safety Standards already in effect.

The EPA Rail Car Noise Emission Standards are based on those noise levels achievable through best practice maintenance. As such, the data used to determine the noise level standards was obtained from noise measurements of typical rail cars which were subject to maintenance requirements no more restrictive than those currently prescribed by the FRA Railroad Freight Car Safety Standards.

Since the data which were used to determine the Rail Car Noise Emission Standards were based on current maintenance requirements, compliance with the noise regulations is not anticipated to cause any additional maintenance burden.

Shell Oil Company, a private car owner, stated that the Federal standards on rail car noise should not apply to privately owned cars because private owners do not have the ability to service cars engaged in interstate commerce.

The Agency replies that while ultimate responsibility and liability for rail car maintenance lies with rail car owners, immediate responsibility and liability is assumed by the rail carrier who is moving the car in interstate commerce, and who does possess the ability to service rail cars.

Section 201.11, 201.12, 201.13 - 365 Day Standard:

The U.S. Department of Transportation (DOT) stated that the 365 day standards provide a disincentive to rebuild old locomotives into compliance or to specify new locomotives be delivered with the mufflers needed to achieve compliance.

Since the Agency has elected to delete the retrofit requirement due to disparities in current cost and technological data, only the second part of the above comment requires consideration. The Agency intends the 365 day standard to be a "best maintenance practice" standard which precludes further deterioration of locomotive noise levels, while allowing adequate time for application of the available technology prior to the effective date of the more restrictive newly manufactured locomotive standards.

C. COMMENT ON ADDITIONAL ISSUES

1. Meeting the Standards with Newly Manufactured Locomotives

The Association of American Railroads and General Motors Corporation both indicated their support of newly manufactured locomotive regulations, and Donaldson Company, Incorporated, stated that the technical and production capability does exist for new locomotive muffler applications. Having received no appreciable comment in opposition to the regulation of newly manufactured locomotives, the Agency has promulgated best technology noise emission standards applicable to locomotives whose manufacture is completed four years from the date of promulgation of the regulation.

2. Meeting the Standard with Existing Locomotives (Retrofit)

a. Economic Considerations

(1) Impact in General

Economic Comments of the Association of American Railroads

The Association of American Railroads (AAR) commented that the EPA vastly underestimated retrofit/muffler introduction costs, with costs actually running between $6,390 and $12,890 per locomotive.

(a) The AAR indicated that the EPA did not properly account for:

(1) Increased annual fuel consumption of 40,000,000 gallons, or 1% of present consumption, at an additional cost of $11,600,000 per annum.

(2) Increased maintenance expenses.

(3) Capital cost of new facilities for retrofit.

(4) Cost of repair to internal parts of locomotives damaged by a poorly working muffler (the direct result of increased backpressure).

(5) Replacement cost of mufflers.

(6) A $14.18/hour labor charge, instead of the EPA figure of $5.80/hour.

(b) EPA underestimated the number of locomotives involved in the retrofit (by 13% error).

(c) EPA underestimated the value of a "locomotive day."

(d) EPA did not take into account the "bottleneck" effect of stoppage at any point in the total operation of the railroad system due to locomotive downtime.

(e) EPA's cost ignores the very important matter of the probable forced retirement of some 1,000 older Alco and Fairbanks Morse locomotives due to retrofit.

(1) The railroads and locomotive manufacturers are currently working at capacity. Any forced retirements would accentuate the locomotive shortage.

(2) Replacement costs would run from $250,000,000 to $400,000,000.

(f) The EPA rationale for using net revenue (in estimation of the financial burden of retrofit in the Background Document) is not explained. Net revenue is irrelevant there; ordinary net income (ONI) should have been used. If O.N.I. had been used, ratios would have been five times as great as those shown in the Background Document.

EPA Responses to Specific AAR Comments

(a)(1) The EPA acknowledges that muffling of locomotives could conceivably cause increased fuel consumption of up to 1% annually, as estimated by the AAR. This percentage is based on an AAR estimate where the mufflers are assumed to create additional backpressure which equals the maximum allowable backpressure specified by locomotive manufacturers' warranties - 5 in. H2O for EMD turbocharged locomotives and 21 in. H20 for EMD Rootes blown locomotives. Since increasing backpressure generally creates a proportionate fuel increase, such worst case backpressure assumptions may be similarly expected to project an estimate of worst case increased fuel consumption.

The Agency believes that the 1% figure is considerably high, since for many locomotives, mufflers may be designed to produce a backpressure which is substantially below the locomotive manufacturers' warranty specifications; hence, fuel consumption increases for those locomotives should be considerably less than the AAR's projected 1% figure.

(a)(2) A concern over increased maintenance expense also presupposes a considerable backpressure increase due to muffler introduction, with increased backpressure causing additional maintenance requirements for internal locomotive parts.

A recent report on computerized muffler design, prepared by B. H Baranek and Newman for the EPA, as well as several instances where test mufflers have been fitted to locomotives, give indication that sophisticated muffler design may restrict backpressure increases to substantially less than manufacturers' warranty specifications upon application to most existing locomotives. This would result in significantly less wear of internal locomotive parts. However, further testing of physical prototype muffler applications would be necessary for a more definitive resolution to this problem.

Maintenance requirement increases are also related to muffler failure rates. Mufflers could be made out of anti-corrosive, heat-resistant alloys for a long service life. Also, an important consideration is the fact that mufflers would be within the carbodies of the locomotives and would not be exposed to the elements, thus extending their expected useful life. Large industrial mufflers have been designed for a useful life of over 20 years and it is expected that locomotive mufflers may be designed for a similarly long life span.

(a)(3) Studies completed by the EPA indicate that the railroad industry currently has approximately 9 percent excess shop capacity. Further information concerning this subject may be found in the Background Document.

(a)(4) Adequate testing of locomotive muffler applications prior to a widespread retrofit program would preclude widespread defective muffler performance, and accordingly, damage of internal locomotive parts due to a poorly working muffler would be a very infrequent occurrence.

(a)(5) As previously mentioned in discussion (a)(2), concerning increased maintenance expense, locomotive mufflers may be designed for a long useful service life and they are protected from the elements by enclosure within the locomotive carbody. Accordingly, they should require minimal and infrequent replacement.

(a)(6) The Agency has conducted further study of the labor rate, and has adjusted its estimated figure from $5.80 to $7.92 per hour. Further information concerning this subject may be found in the Background Document.

(b) The EPA acknowledges this incorrect estimate and has included a 13.7% increment in its current retrofit cost analysis.

(c) The Agency has reviewed its estimate of the value of a "locomotive day" and has arrived at a revised estimated value of $560, as opposed to the EPA's original estimate of $1257. Further information concerning this subject may be found in the Background Document.

(d) The Agency believes that enforcement regulations will be promulgated which will be sensitive to locomotive scheduling and therefore will avoid any major cumulative disruption of rail services.

(e) EPA data indicates that the some 1,000 older Alco and Fairbanks Morse locomotives in question are currently being retired at a rapid rate, indicating that virtually the entire population of such locomotives would be retired prior to the proposed 4-year effective date of the retrofit requirement. However, this is no longer a relevant concern due to the fact that retrofit has been deleted from the regulation as promulgated.

(f) The EPA elected to use net revenue as opposed to ordinary net income in the Background Document's estimate of the financial burden of retrofit because the Agency believes that net revenue is a better measure of the firm's ability to meet short run operating expenses of the type incurred in a locomotive retrofit program.

Other Economic Comment

The DOT estimated $153 million for retrofit as opposed to original EPA estimates of $80 million to $100 million dollars, and Donaldson Company, Incorporated, indicated that muffler and accompanying hardware costs will be 2 or 3 times higher than estimated in the Background Document, with costs depending heavily on the amount of auxiliary hardware required to overcome space and backpressure limitations.

Retrofit largely involves the phased addition of mufflers to the existing locomotive fleet. Several docket entries contained economic and technological data which conflict significantly with the EPA data which appears in the Background Document. The principal areas of conflict involve disparities in determination of the "best available technology" as it exists today and the resultant costs of its application. There exists a further complicating factor in that the available space configurations existant within many locomotives have been altered over the years due to the addition and modification of various locomotive components such as dynamic braking systems and spark arresters. As a result of this practice there exist today numerous and diverse locomotive configurations, each possessing its own specific peculiarities which must be accounted for in a retrofit program. The implications of this diversity of locomotive configurations and the accompanying disagreement concerning available technology and the cost of its application (i.e., labor rates, capital costs of new facilities, etc.) have given rise to cost of compliance figures which range from the EPA's original estimates of $80 to $100 million to industry estimates approximating $400 to $800 million. Although the generation of additional information concerning the availability of technology may allow the Agency to reconcile these widely varying retrofit cost estimates, the collection of such data would be a costly and time consuming process which may produce a retrofit cost estimate which remains substantially high relative to the public health and welfare benefits which would result, especially in view of the fact that railroad noise has not been identified as one of the major sources of noise in the environment. For these reasons the Agency has decided to remove the retrofit requirement from the regulation being promulgated herein. Acknowledging the uncertainties which currently accompany the retrofit provision, the Agency may reconsider the retrofit issue and may promulgate a retrofit requirement should further information indicate that the technology is available and that retrofit compliance costs are reasonable, relative to the health and welfare benefits to be accrued.

(2) Economic Impact on Bankrupt/Marginal Railroads:

The Association of American Railroads, Mr. R. Harnden, and Mr. K. K. King, expressed concern that the regulations as proposed may have substantial adverse economic impact upon the bankrupt and marginal railroads.

The Agency has endeavored to anticipate and account for all costs which the bankrupt railroads specifically, and all railroads generally, may incur as the result of this regulatory action. Best and worst case estimates for the sum of equivalent annual manufacturing costs and equivalent annual fuel costs over 25 years, vary from $4.59 million to $4.76 million for the entire railroad industry. The fractional impact of these costs on the marginal and bankrupt railroads is expected to be approximately 28 percent of the total cost to the entire railroad industry, with such costs not seen as being significant in comparision to other costs regularly incurred by such railroads.

(b) Technical Considerations

The Association of American Railroads (AAR), the Illinois Railroad Association (IRA), and Donaldson Company, Incorporated, indicated concern that mufflers may cause excessive backpressure when applied to locomotives, especially when coupled with spark arresters. The AAR, and the Salt River Project, of Phoenix, Arizona, indicated that this backpressure increase will cause an increase in fuel consumption, with the AAR also warning of increased chemical and particulate air emissions.

Mufflers can be designed which are well within the manufacturer's warranty backpressure specifications, for both Rootes blown and turbocharged locomotives, for use both with or without spark arresters. Mufflers which are within these specifications should cause only insignificant increases in atmospheric pollutant emissions and a minimal increase in fuel consumption.

The Forestry Department of the State of Oregon urged the EPA to carefully consider the production and control of carbon particles in the locomotive exhaust, and the Association of American Railroads

(AAR) indicated that carbon collection in mufflers presents a potential fire hazard.

The EPA has given careful consideration to the production and control of carbon particles and sees no indication that properly designed locomotive mufflers will interfere with effective spark arresting.

Harco Manufacturing Company, a member of the muffler manufacturing industry, reinforced this posture in their docket response, expressing their professional opinion that effective mufflers can be designed to integrate with spark arresters, while keeping within available space limitations.

Presently there is no substantial indication that carbon collection in locomotive mufflers would present a potential fire hazard. Within spark arresters which are currently found on today's locomotives, carbon particles are gathered from the exhaust gases prior to the passage of those gases through the outlet section of the spark arrester for discharge through the exhaust pipes. While it could be postulated that hot carbon might conceivably collect within mufflers which are in tandem with or are integrated into spark arresters, it could also be postulated that such carbon collection might just as readily occur at the outlets of spark arresters or within exhaust pipes which are presently found on locomotives. However, no such fire hazard due to carbon collection has been evidenced at spark arrester outlets or in exhaust pipes, and the Agency sees no indication that the installation of mufflers will substantially increase the potential for such a fire hazard.

The Association of American Railroads (AAR) indicated concern that increased railroad rates to cover compliance costs may cause diversion of traffic to more fuel intensive modes which also emit more atmospheric pollutants.

Original Agency analysis of this issue indicated that retrofit costs would, in themselves alone, be insufficient to cause a major increase in railroad freight rates. This EPA estimation was largely attributable to the relatively low magnitude of retrofit costs in comparison to total railroad costs and operating expenses. A further contributing factor is the fact that a large and increasing proportion of railroad tonnage involves the transport of bulk commodities and raw materials such as grain and coal for which there is generally little cross-elasticity between the major land transport modes. Further information on this subject may be found in the Background Document.

The Association of American Railroads (AAR) indicated that the application of mufflers will result in decreased reliability of the locomotives both with respect to failure of the mufflers themselves and to other components of the locomotives.

Mufflers could be made out of anti-corrosive, heat-resistant alloys for a long service life. Also an important consideration is the fact that the muffler would be within the carbody of the locomotive and would not be exposed to the elements, thus extending its expected useful life. Large industrial mufflers have been designed for a useful life of over 20 years and it is expected that locomotive mufflers may be designed for a similarly long life span. Also, the design and utilization of mufflers which are within manufacturers' backpressure specifications, should preclude major adverse effects to other internal locomotive components.

Donaldson Company, Incorporated, indicated that they see little problem with the retrofit of switcher locomotives, but that a visibility restriction, however, may hinder direct application of the muffler to the switcher's hood.

Donaldson further indicated that the retrofit of road locomotives will be more difficult, with the retrofit of turbocharged locomotives the most difficult of all. They attributed this difficulty to the lower back-pressure and greater space restrictions of turbocharged engines, explaining that these space restrictions are further complicated by the fact that turbocharged locomotives require large size mufflers due to their large air flow. Donaldson stated that the necessary technology is available to retrofit turbocharged locomotives; however, considerable design ingenuity will be required to ensure its successful application.

Donaldson Company indicated its agreement that mufflers can provide between 8-10 dB(A) attenuation (locomotive exhaust noise at 100 ft., full throttle), but beyond that noise reduction level, other noise sources become dominant.

The Association of American Railroads (AAR) indicated that exhaust muffler manufacturers would have difficulty in designing mufflers for particular engines, unless they knew all the parameters of the engines involved. Donaldson Company reinforced this opinion by stating that they do not have the capability to develop muffling/silencing systems independently of the railroads or locomotive manufacturers.

Since the regulation is now applicable to only newly manufactured locomotives, the Agency foresees no problem with the coordination of both locomotive engine and muffler design in order to achieve new locomotive compliance.

3. Health and Welfare.

E. Schmidt, R. Harnden, K.K. King, and the City of Bloomfield, New Jersey, indicated that the EPA did not provide adequate information as to the number of people impacted by railroad noise nor the number to be benefited by the regulation. The Association of American Railroads called for information as to whether such people were adversely affected from a health and welfare standpoint initially.

The Agency included in the Background Document studies and data which indicated that the number of people exposed to various noise levels by railroad traffic are significant. Such numbers appear to be approximately 2.29 million people at an Ldn value of 55 dB(A). Exposure to such noise levels for extended periods of time has been determined to have an adverse effect on the health and welfare of those exposed, as indicated in an EPA report of March 1974 entitled "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety." In addition the EPA is establishing this regulation as part of a regulatory strategy that, according to Agency analysis, could eventually relieve approximately 520,000 people from railroad noise levels in excess of 55 dB(A), Ldn.

E. Schmidt, R. Harnden, K.K. King, and the Salt River Project, contended that the health and welfare of people is not affected by railroad equipment which operates in sparsely populated or rural areas and that, therefore, the regulation of such equipment is not called for.

The Agency has determined that there is substantial mobility of the use of railroad equipment not only within particular railroad operating regions but across the nation as a whole, and that such mobility is an important facet of the manner in which railroad companies operate. This mobility is evidenced by the fact that rail cars and locomotives are transferred from one area to another in order to satisfy the fluctuations in required hauling capacity which take place, and by the practice whereby old line locomotives are retired by transferring them to railroad yards to act as switchers. It has been found that such mobility is increasing as evidenced by Railbox, a plan utilized by a growing number of railroads whereby rail cars are pooled so that their use may be shared anywhere within the operating regions of the participating railroads.

The Agency has determined, therefore, that the mobility of rail cars and locomotives requires that the standards be applied uniformly to all such pieces of equipment.

4. Legal Considerations.

The Association of American Railroads raised a number of legal questions in its comments to the proposed regulation. These questions dealt primarily with the scope of the Agency's duties and authority under the Noise Control Act of 1972, and Section 17 in particular, as they apply to the Agency's decision not to regulate all railroad facilities and equipment at this time, and with the Agency's interpretation of the preemptive effect of the regulation.

The AAR indicated that the EPA has improperly exercised its authority to regulate noise from the operation of railroad facilities and equipment in that, as a matter of statutory interpretation, all railroad noise sources must be regulated according to the Noise Control Act of 1972.

The Agency, after an analysis which considered the language of the statute as well as its legislative history, feels that it does have the authority to decide and indeed should decide what priority should be given to the regulation of various sources of railroad noise, all of which differ in their impact upon the society and the need for their uniform regulation. The EPA does not take the position that there are any sources of railroad noise that it will not regulate. The Agency may consider the possible regulation of other sources of railroad noise under Sections 6, 8, and 17 of the Act, and may regulate such additional sources as the need for and feasibility of such regulation becomes established.

The AAR also questioned whether the Agency has the authority to offer an opinion as to the preemptive effect of its regulations, and in particular, felt that, contrary to the Agency's stated position, the setting of Federal emission standards for locomotives and rail cars preempts every effort to control noise from that same equipment by local and State authorities, such as the required erection of noise barriers, or the regulation of overall rail road yard noise.

The EPA believes that the Noise Control Act of 1972 is clear in its contemplation that Federal and State governments work together in the control of noise. However, the Act also provides, in some cases, that the Federal authority be preemptive. The Agency therefore feels that it is proper for it to explain the extent of its regulations and to indicate the point beyond which the States and local governments may act; and that it is not prohibited from assisting the State and local governments by indicating ways in which the Agency believes they may augment its regulatory efforts. In addition the EPA's analysis indicates that, based on legal precedents, subsections 17(1) and (2) provide only for the preemption of State and local regulations which set standards on the noise emissions of Federally regulated equipment or facilities, or which have that effect by requiring the modification of such equipment or facilities, or the alteration of their use.

The Illinois Railroad Association indicated that State and local governments do not have the inclination or ability to determine the technical feasibility and cost of compliance of noise regulations and, therefore, the EPA is not acting in accordance with the instructions of Congress by encouraging such local initiative.

The Agency believes as stated above that the Congress did intend that the Federal and State authorities cooperate in the control of noise. Certain States, in particular California, and Illinois, have well established environmental agencies and have enacted and are enforcing comprehensive noise regulations. These States and others are clearly not devoid of technical and economic expertise. It appears to the Agency, therefore, that there is no fundamental reason why such States should not be permitted and encouraged to consider the technology available within relevant economic restraints to solve those noise problems peculiar to them that are not preempted by Federal regulatory action.

5. Measurement Methodology and Compliance Regulations.

The National Rail Passenger Corporation (AMTRAK) and the DOT recommended that the EPA specify the following sound measurement parameters in the regulation: wind velocity, humidity, ambient noise, test site characteristics, test equipment orientation, and test operator location. In addition the DOT and the New York State Department of Environmental Conservation included suggestions for types of test equipment that should be utilized, and the New York D.E.C. also requested the specification of error tolerances within the measurement procedures.

The proposed regulation did not include a detailed measurement methodology since it was contemplated that such would be included as part of the compliance regulation to be promulgated by the DOT. Such measurement methodology, dealing with the enforcement aspects of railroad noise measurement, will still be developed by the Department of Transportation. The Agency, however, as a result of its own further analysis and after consideration of the questions and suggestions received during the public review process, has decided to incorporate additional measurement criteria into the standards as an added subpart of the final regulation being promulgated. Such measurement criteria contain specifications for ambient noise, wind noise, test site conditions, test equipment orientation, and other parameters necessary for the consistent and accurate measurement of the sound levels specified in the regulation.

This decision was made due to the complexity of the problem of accurately and fairly performing noise measurements of railroad equipment, and because the Agency felt it necessary to ensure that the standards within the regulation be fully and definitively specified so that there be no question as to the standards promulgated. The proper and complete definition of such standards is particularly critical with respect to railroad noise because there is no generally accepted measurement scheme in use nationally or throughout the affected industry unlike the situation in other industries subject to Federal noise regulation.

G. W. Kamperman indicated that the C scale would be more appropriate for this regulation than the A scale.

It has been argued that the A-weighted sound level discriminates against low frequencies and, thus, should be replaced by the C-weighted sound level. However, the ear also discriminates against low frequencies so that at low frequencies the sound pressure level must be comparatively high before it can even be heard. Since the correlations between A-weighted sound level and human response are consistently better than that obtained with the C-weighted sound level, the EPA believes that the measurement procedures using the A scale on which these regulations are based are appropriate, and therefore, no change has been made.

The Cook County, Illinois Department of Environmental Control and the New York State Department of Environmental Conservation expressed concern over the 100 foot measuring distance and indicated that the specificiation of a 100 foot measuring distance in the standards is too far because such would require that too large an area be cleared for the necessary measurement site.

The Agency believes from the analyses used to develop the regulation and from its study associated with the development of measurement criteria that the 100 foot measuring distance does not appear to create significant problems with finding suitable sites for the measurement of the sound levels associated with any of the standards, and has therefore not changed such distance.

The DOT requested more than 270 days to develop compliance regulations due to the complexity of the nature of railroad noise control and because existing experience and expertise in the field are so limited.

The Agency is aware of the problems associated with the regulation of railroad noise and is concerned that adequate time be provided so that comprehensive and effective compliance regulations may be developed. While it has taken upon itself the development of detailed measurement criteria which are being incorporated as part of the final regulation, the Agency recognizes the need of the DOT for adequate time to develop the compliance regulation. Therefore, in direct response to the request of the DOT, the effective date of the Best Maintenance Practice Standards has been changed from 270 days to 365 days from the date of promulgation.

The Agency realizes that unforeseen difficulties may occur and it will therefore attempt to work closely with the DOT in the development of the compliance regulations so that appropriate measures may be taken should such difficulties arise.

6. Special Local Conditions

The City of DesPlaines, Illinois; the City of Bloomfield, New Jersey; and the City of Chicago Department of Environmental Control, all requested that local railroad noise regulations not be prohibited by the EPA's regulatory action. In addition, Citizens Against Noise, the City of Bloomfield, New Jersey, and the City of Chicago Department of Environmental Control indicated that separate specialized noise regulations such as those that would control railroad noise emissions in highly populated areas, especially at night, should be included in the Federal regulatory strategy or allowed on the local level.

The Agency recognizes and agrees with the language in the Noise Control Act of 1972 which envisions a cooperative effort between local, State and Federal governments in the control of noise. All of the types of regulatory action mentioned by the commenters will not necessarily be prohibited by this Federal regulatory action. The Agency has explained the nature of the preemptive effect of its regulations in the Preamble to the regulation and feels that such explanation should serve as a guide to the future status of such State and local regulatory efforts. As interpreted there by the Agency, State and local governments may exercise regulatory authority as provided in section 17 (c)(2) as well as for equipment and facilities not covered by Federal regulation, and are encouraged to do so, so long as such regulation is within relevant technical and economic constraints and does not impose a significant burden on interstate commerce.

The City of DesPlaines, the Minnesota Pollution Control Agency, J. Palmer, and the City of Chicago Department of Environmental Control had comments which dealt specifically with the interpretation of the provision in the Act for special local determinations.

The Agency believes that Section 17(c)(2) is intended to provide certain limited relief from a uniform national standard due to "special" local conditions. However, Section 17(a) calls for such uniform national standards and these could be significantly diluted through an overly broad interpretation of what constitutes special local conditions. The Administrator, under Section 17(c)(2) of the Act, will make specific case by case determinations which, in his judgment, balance the need for national uniformity against the need for exceptions to the national regulations in particular situations.

The South Carolina Department of Health and Environmental Control requested that the standards be reviewed periodically and strengthened as technological advances are made.

The Agency fully intends to continue to review the field or railroad noise control and may propose revisions to the regulations as such revisions become technically and economically feasible.

The Illinois Railroad Association indicated that local governments were free to make the Federal regulation meaningless by the exercise of their non-preempted regulatory authority.

State and local governments in exercising their non-preempted regulatory authority, as explained by the Agency under its discussion of preemption, may not issue regulations which set standards on the noise emissions of Federally regulated equipment or facilities, or which have that effect by requiring the modification of such equipment or facilities or the alteration of their use, and thus the Agency sees no problem with the Federal regulations being circumvented.

7. Property Line Standards.

The DOT and the City of Bloomfield, New Jersey, requested that the EPA impose property line standards on railroad noise using an L10 noise level standard.

The use of property line noise standards is applicable primarily to the regulation of noise from fixed facility and area noise sources. In the regulation of railroad noise such sources include maintenance shops, marshalling yards, humping yards, and terminals. Since EPA has not covered these facilities in the regulation, the use of such area noise level standards in the regulation is not appropriate.

8. Background Document Data and Information.

General Motors Corporation (GM) questioned the validity of the 6 dB(A) conversion factor for changing measurements made at 50 feet to an equivalent 100 foot value, due to the length of the locomotive.

Agency analysis indicates that any slight inaccuracy which may exist in the use of the 6 dB(A) conversion factor for the conversion of locomotive noise levels measured at 50 feet to 100 foot levels, is in fact a conservative error which understates the actual noise level as it would be recorded by a physical measurement at 100 feet. Accordingly, some of those locomotives whose noise levels have been measured in this manner may emit actual noise levels at 100 feet which are in fact slightly lower than those levels described by EPA data which were converted from 50 feet. Such locomotives may in fact require less quieting than is suggested by the 50 foot data, and as such may be more easily brought into compliance with the noise standards. The Agency emphasizes that any inaccuracy inherent in using the conversion factor is slight and has minimal effects upon the data so converted.

General Motors also stated that page 5.3 of the Background Document claims that mufflers will provide 6 dB(A) reduction of all locomotive noise levels. They further indicated that a 6 dB(A) reduction is not always possible, and that 87 dB(A) at 100 feet would be a better statement than a 6 dB(A) reduction.

The above GM comment is apparently attributable to an incorrect interpretation of the Background Document. The standards being promulgated by the EPA require an absolute noise level of 87 dB(A), not a net reduction of 6 dB(A). Specifically, the Background Document states: "Based on the considerations of available empirical data, an overall noise reduction of 6 dB(A) for the noisiest (emphasis added) seems reasonable. Accordingly, the application of exhaust mufflers can be expected to permit all locomotives to to achieve the following levels: Idle - 67 dB(A) (now 70 dB(A)); Overall Maximum - 87 dB(A)."

GM further indicated that based on the magnitude of the one-third octave band levels, the measurements on p. 4-13, Figure 4-2, appear to have been made at closer to five feet than 55 feet as specified when measuring the noise emissions of an EMD GP4O-2 locomotive.

An investigation of Figure 4-2 in the Background Document does indicate that the recorded noise levels are inordinately high. These high readings are attributable to the increased projection of fan and casing radiated noise due to open engine access doors during the testing. However, the intent of this figure and its supporting discussion was not to quantify the absolute noise levels due to fan noise, but to demonstrate that fan noise is in fact an appreciable noise source. To quote from page 4-13 of the Background Document: "Since it was necessary to open the engine access doors during the measurements, the recorded levels are somewhat higher than would be generated under normal operating conditions. However, there is little doubt that cooling-fan operation can contribute significantly to overall levels." Although Figure 4-2 does not purport to accurately quantify cooling-fan noise levels under normal operating conditions, it does succeed in its primary purpose which is to demonstrate the relative significance of cooling-fan noise.

9. Statements of Support

Of the 29 docket submissions received by the Agency, the following 6 expressed general and often enthusiastic agreement with the proposed regulations: The Oregon Department of Environmental Quality, the Illinois Environmental Protection Agency, the Harco Manufacturing Company, the City of Chicago Department of Environmental Control, the South Carolina Department of Health and Environmental Control, and the Office of Environmental and Planning Studies of the University of Illinois Law School at Urbana Champaign.

In addition, the Department of Transportation expressed agreement with the standard for locomotive operation under moving conditions, and the New York State Department of Environmental Conservation expressed agreement with and gratitude for the inclusion of a detailed description of the preemptive effect of the regulation in the preamble.

D. SYNOPSIS OF COMMENTS FROM THE SPECIAL CONSULTATION MEETING ON THE PROPOSED RAILROAD NOISE EMISSION REGULATIONS

Introduction:

On August 14, 1974, a special consultation meeting was held in Des Plaines, Illinois, concerning the Proposed Interstate Railroad Noise Emission Regulations. The transcript of the meeting is included as part of the total body of public comment received by the Agency.

Since all of the comments raised at this meeting have been addressed elsewhere in this document the following section will consist only of a listing of the particular comments received.

Summary of Comments:

Citizens Against Noise requested that separate standards be promulgated for rural and urban areas, since the effects of railroad noise on people are so much greater in the latter than the former. In addition the regulation or elimination of railroad acoustical warning devices was called for as well as the inclusion of subway and elevated trains in the regulation.

M. Schiep requested that the 4 year effective date of the regulation be reduced.

The City of Des Plaines expressed concern that local ordinances that have produced meaningful noise control of railroad equipment will be eliminated by the preemptive effect of the Federal regulation. Also called for was a delineation of the meaning of special local conditions as used in the Noise Control Act of 1972.

General agreement with the proposed regulation was expressed by the Illinois Environmental Protection Agency.

The Minnesota Pollution Control Agency requested clarification of how and why the EPA had preempted track and right of way without at the same time regulating such. In addition clarification was requested of the definition of Interstate Carrier as used in the Act.

The City of Bloomfield, New Jersey, indicated that property line noise level standards should be imposed along with more strict noise level standards for locomotives and rail cars. A reduction of the 4 year time period for the application of the stricter standards was also called for.

R. Beauchard requested clarification of how the measurement methodology for the regulation would be promulgated.

Kamperman Associates, Inc., commented that they felt the C-scale was better suited to measure locomotive noise than the A-scale.

The Cook County, Illinois Department of Environmental Control expressed concern that the 100 foot measuring distance was too far and would require too much open area for compliance measurements.

The Harco Manufacturing Company asked that EPA consider the effects on the utilization of spark arresters of the proposed regulation.

The City of Chicago raised questions with respect to the extent of Federal preemption in limiting the local and State governments from enacting and enforcing noise regulations relative to railroad noise.

INDEX OF WRITTEN DOCKET SUBMISSIONS

DOCKET NO.	PERSON OR ORGANIZATION
R001	Mr. B. Leath
R002	State of New York, Department of Environmental Conservation, Albany
R003	Association of American Railroads submission of August 7, 1974
R004	Shell Oil Company
R005	ADM Company
R006	Deleted EPA Region III's Comment, which will be considered apart from the formal docket
R007	Ritchies Furniture Company
R008	Mr. R. Weinrich
R009	Mr. R. Harnden
R010	Mr. E. Schmidt
R011	U.S. Department of Transportation (DOT) Exhibits 1-2, Attachments A-C
R012	Illinois Railroad Association (IRA) Exhibits A-K
R013	Association of American Railroads (AAR)
R014	Harco Manufacturing Company
R015	Department of Environmental Quality, Portland, Oregon
R016	Fruit Growers Express Company, et al
R017	Salt River Project, Phoenix, Arizona
R018	National Railroad Passenger Corportation (AMTRAK)
R019	Illinois Environmental Protection Agency
R020	Donaldson Company, Inc.
R021	Minnesota Pollution Control Agency
R022	University of Illinois at Urbana/Champaign

DOCKET NO.	PERSON OR ORGANIZATION
R023	Forestry Department, Salem, Oregon
R024	Town of Bloomfield, New Jersey
R025	General Motors Corporation (GM)
R026	Mr. K.K. King
R027	Deleted (irrelevant letter)
R028	South Carolina Department of Health and Environmental Control
R029	City of Chicago, Department of Environmental Control

INDEX OF SPECIAL CONSULTATION MEETING PARTICIPANTS

DOCKET NO.	PARTICIPANT
5030	Mr. Theodore Berland, President, Citizens Against Noise
5031	Mrs. William Schiep
5032	Mr. Phillip Lindahl, Environmental Officer for the City of Des Plaines
5033	Mr. N. D. Povair, Supervisor, New Jersey Environmental Protection and Noise Control
5034	Mr. Thomas Greenland, Attorney for Chicago and Northwestern Railroad
5035	Mr. Robert Helwig, Jr., for Illinois Environmental Protection Agency
5036	Mr. Al Perez, Minnesota Pollution Control Agency
5037	Mr. John Steven Newman, City of Chicago, Department of Environmental Control
5038	Mr. DiLeonard, Counsel for City of Des Plaines
5039	Mr. Henry Sant'Ambrogio, for the Town of Bloomfield, New Jersey
5040	Mr. D.N. Trafalette, for the Association of American Railroads
5041	Mr. Simtana, Cook County Department of Environmental Control
5042	Mr. J. Palmer
5043	Mr. G.W. Kamperman, Kamperman Associates